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ORIGINAL ARTICLES

FFECTS OF EARLY EARTHING-UP OF SUGARCANE ON THE ATTACK OF THE STEM BORER, *ARGYRIA STICTICRASPIS* HMPSN.

By B. D. Gupta, M.Sc., Assoc. I.A.R.I., Sugarcane Research Station, Muzaffarnagar

(Received for publication on 25 August 1943)

RTHING-UP of sugarcane plants during rains has en recommended by Sethi, *et al.* [1937] as a rmal cultivation procedure to prevent the crop m lodging both when planted in trenches or flat.

Early earthing-up as a measure to control the mage done to shoots by the sugarcane moth rer, *Argyria sticticraspis* Hmpsn, was recommend- for the first time by Subramaniam and Ramiah 935]. The experiments conducted at Govern- nt Sugarcane Farm, Mandya (Mysore State), owed that by a light earthing-up, the soil on th sides of the cane rows is thrown over the ung shoots and when this is followed by irriga- n, the soil settles down in the space between the st leaf-sheath and the plant stalk. This opera- n prevents the borer from living as a leaf miner the first leaf sheath prior to its entry into the ne stalk. The method of control was observed Mandya to reduce borer attack by more than per cent without in any way interfering with e tillering and vigour of the crop.

On the basis of this recommendation, experi- nts were taken up at the Sugarcane Research tion, Muzaffarnagar, to study the effects of ly earthing-up on the incidence of *A. sticti- spis*, the most serious of the sugarcane borers ring the hot weather months of May and June. dies were also carried out on the effects of ly earthing on tillering, cane formation, yield l maturity of the crop. The results obtained ing three crop seasons, 1937-38, 1939-40 and 0-41 are given in the present paper.

Experimental

The planting of sugarcane in the western dis- cts of the United Provinces is generally done ing March. The shoots of the new crop appear ing the fourth week, after planting. It is er the middle of April that *A. sticticraspis* grates to plant crop, after completing its first od in the ratoon crop during March and April. e drying up of the central leaf-sheath is the t sign of the commencement of borer attack. e borer infestation up to the middle of May is fined to a small percentage of plants, varying n 2 to 8 per cent. After this period the in- ation increases with the progress of the hot ather and continues to be heavy upto the middle July, when it begins to decline and gradually dies off with the progress of the monsoon rains in August.

Preliminary observations on the various effects of early earthing-up were made in 1936 on a non-replicated plot basis. One earthing by the middle of May brought down borer attack by 12 per cent in comparison to crop earthed-up in August. The tillering was reduced by 50 per cent canes formed were less by 28 per cent and yield by 10 per cent in comparison to the normal crop. The individual weight of sticks in the earthed-up plot increased by about 20 per cent and there was no material effect on the sugar contents. It was also observed that the irrigation after earthing-up washed down most of the soil raised up to protect the tender stalks of the plants from borer attack. In subsequent field trials, laid out in randomized blocks with four replications each year, earthing was carried out at the time of hoeing after irriga- tion. Three, two and one earthing followed from the middle of May, middle of June and middle of July, respectively, were compared with no earthing during 1937-38 and 1939-40. During 1940-41 the interval between various earthings was reduced from one month to a fortnight in the treated plots, with the result that the various earthings finished by the middle of June and in order to prevent the crop from lodging during rains, a final earthing-up was carried out in August in all the plots.

The incidence of borer attack was recorded by making counts of all the healthy and infested shoots in the four replications of the treated and control plots. The size of an individual plot was 1/27.4 acre in 1937-38 and 1/23.3 acre in 1939-40 and 1940-41. The observations were recorded before the first earthing was carried out and were repeated at fortnightly intervals till the middle of September when the borer attack almost dis- appeared. The 'dead hearts' or the central whorl of dried-up leaves were pulled out from the infested plants, in such a way, that the borer was left behind in the plant stalk. The method of digging out the infested plants was not adopted as it would have interfered with the natural inci- dence.

Effect of earthing on borer incidence

The effect of earthings on the borer incidence is shown in Table I. The records of borer infesta- tion include a short percentage of the root borer

TABLE

Early earthing and

Crop season	Treatment	Dates of earthings	Variety	Number of shoot		
				Up to 15 May	From 16 May to 15 June (1st round)	Decrease in borer attack compared to unearthed-up plots
1	2	3	4	5	6	7
1937-38. . .	A—Three earthings	16/5, 16/6 and 16/7	Co. S. 70	356	9124	44·1%
	B—Two ,, .	16/6 and 16/7 .	,, .	329	15317	Unearthed-up
	C—One ,, .	16/7 . . .	,, .	438	15289	,,
	D—Control .	...	,, .	301	18385	,,
Critical difference at 5 per cent level	..	...	...	...	...	...
1939-40 . .	A—Three earthings	16/5, 16/6 and 16/7	Co. S. 70	2004	8062	34·6%
	B—Two ,, .	16/6 and 16/7 .	,, .	1072	11324	Unearthed-up
	C—One ,, .	16/7. . .	,, .	1328	12302	,,
	D—Control .	...	,, .	1351	13347	,,
Critical difference at 5 per cent level	...	...	...	...	...	...
1940-41 . . .	A—Three earthings	16/5, 1/6 and 16/6	Co. S. 178	1538	9005	41·01%
	B—Two ,, .	1/6 and 16/6 .	,, .	1491	9926	35·01%
	C—One ,, .	16/6 . . .	,, .	1678	15448	Unearthed u
	D—Control .	...	,, .	2027	15098	,,
Critical difference at 5 per cent level	..	...	...	...	...	...

I

orer attack

estroyed per acre					Total No. of shoots destr yed per acre from May to September	Per cent decrease in borer attack due to earthing-up
From 16 June to 15 July 2nd round)	Decrease in borer attack compared to unearthed-up plots	From 16 July to 15 August (3rd round)	Decrease in borer attack compared to unearthed-up plots	After 15 August		
8	9	10	11	12	13	14
4904	19·2%	1151	4·6%	...	15536	40·7%
4658	23·3%	1096	9·1%	...	21399	18·3%
5836	Unearthed-up	1370	—13·6%	...	22933	12·4%
6302	,,	1206	Unearthed-up	...	26194	...
...	...	...	...	...	5453	...
5592	14·4%	1165	10·7%	140	16962	18·8%
5452	16·6%	1235	5·4%	92	19176	8·1%
6338	Unearthed-up	1561	—19·2%	92	21622	—3·5%
6734	,,	1305	Un-earthed-up	140	20877	...
...	...	...	...	...	Insignificant	...
4893	44·4%	746	23·6%	163	16333	39·9%
3961	55·02%	489	50·0%	140	16007	41·1%
5219	40·7%	489	50·0%	140	22981	15·4%
8807	Unearthed-up	978	Un-earthed-up	256	27168	...
...	...	...	...	...	1636	..

TABLE

Effect of early earthing

Crop season	Variety	Treatments	Date of planting	Per cent germination middle of May	Tillers	
					Per acre on 15 July	Per cent increase or decrease in comparison to control
1	2	3	4	5	6	7
1937-38 . . .	Co. S. 70 . .	A—Three earthings	22/3/1937	40·4	87433	12·9%
	,, . .	B—Two ,, .		39·1	91653	8·7%
	,, . .	C—One ,, .		41·2	96558	
	,, . .	D—Control .		40·8	104284	
Critical difference at 5 per cent level	...	...	...	...	8334	
1939-40 . .	Co. S. 70 . .	A—Three earthings	10/3/1939	40·4	73558	12·3%
	,, . .	B—Two ,, .		36·4	77007	8·2%
	,, . .	C—One ,, .		39·9	87165	
	,, . .	D—Control .		35·0	80548	
Critical difference at 5 per cent level	...	...	...	...	6149	...
1940-41 . .	Co. S. 178 . .	A—Three earthings	16/2/1940	41·0	52564	25·5%
	,, . .	B—Two ,, .		40·5	48370	31·4%
	,, . .	C—One ,, .		44·9	66428	5·8%
	,, . .	D—Control .		45·8	70552	
Critical difference at 5 per cent level	...	...	...	...	2584	...

II

on the crop

Canes			Yield per acre			Juice analysis		
Formed per acre	Per cent increase or decrease in comparison to control		In maunds	Per cent increase or decrease in comparison to control		Per cent sucrose in juice	Purity coefficient	
8	9		10	11		12	13	
57303	15/10/37	8·6	657·1	20/4/38	8·5	12·4	20/4/38	76·00
60280		5·6	707·5		16·9	13·9		80·2
62145		2.7	666·4		10·1	12·5		76·4
63842			605·3			10·5		70·3
3444	...		Insignificant		...	...	...	
41450	31/1/40	4·2	799·8	31/1/40	13·3	13·0	1/2/40	76·4
42140		5·9	789·3		11·8	12·9		75·7
41965		5·5	753·4		6·7	13·0		76·3
39795			706·0			13·2		77·1
Insignificant	...		60·9	...		...	...	
31455	8/2/41	11·2	453·0	8/2/41	1·9	16·5	16/2/41	86·3
30499		13·9	458·0		0·9	16·0		87·4
33552		5·3	482·8		4·5	16·4		87·3
35439			462·0			17·1		87·9
1682	...		Insignificant	...		...	...	

Emmalocera depressella Swinh, which in the early part of the season occur much in the same way as the larvae of *A. sticticraspis* and cannot be easily differentiated from each other from the nature of the 'dead hearts'.

A reference to Table I will show that 20 to 27 thousand shoots per acre are destroyed by the dead heart borers, during the crop season, from May to September. The greatest damage to the shoots occurs during the period of about a month, from the middle of May to the middle of June. One earthing carried out by 16 May went a long way to protect the plants from borer attack. It was observed on 15 June, prior to the second earthing-up that there was a decrease in the number of damaged shoots in the earthed-up crop (Treatment A) by 44 per cent in 1937 and 35 per cent in 1939 when compared with the unearthed-up crop in treatments B, C and D. During this period two earthings were given, first on 16 May and second on 1 June in treatment 'A' and one earthing on 1 June in treatment 'B' of 1940 crop. This resulted in a decrease in borer attack by 41 and 35 per cent respectively in comparison to unearthed-up crop in treatment 'C' and 'D'.

In the second round, i.e. between the middle of June and middle of July, the intensity of attack was 50 per cent less as compared to the first round. An earthing carried out by the middle of June in plots earthed-up in May (Treatment 'A') showed on 15 July a decrease in the number of borer-damaged shoots by 19·2 per cent in 1937 and by 14·4 per cent in 1939, in comparison to treatments 'C' and 'D' which were unearthed-up. A decrease by 23·3 per cent in 1937 and 16·6 per cent in 1939 was recorded in treatment 'B' where earthing was carried out for the first time on 16 June. By this time, three, two and one earthings had been given in the 1940 crop where a decrease in the number of damaged shoots by 44·4, 55·2 and 40·7 per cent was recorded in treatments A, B and C respectively, in comparison to the corresponding damage in the unearthed-up crop.

The borer attack during the period from the middle of July to the middle of August or afterwards is not severe as shown in Table I, treatment 'D' column 10. An earthing carried out on 16 July in twice earthed-up plots (Treatment A) showed a decrease in borer attack by 4·6 per cent in 1937 and 10·7 per cent in 1939, while in plots earthed-up but once (Treatment B) there was decrease by 9·1 per cent in 1937 and 5·4 per cent in 1939. An earthing carried out for the first time on 15 July in Treatment 'C' in 1937 and in 1939 did not bring about any material decrease in borer attack. A decrease varying from 23·6 to 50 per cent was recorded on 15 July in earthed-up plots (Treatments A, B and C) in 1940 in comparison to control.

Effect of early earthing-up on the crop

(*i*) *Tiller formation.* Earthings were commenced by the middle of May when about 40 per cent of the eye buds planted had germinated (Table II, column 5). As a result of two earthings, one on 16 May followed by another on 16 June in Treatment A (Table II, column 7), tillering decreased by about 13 per cent in July in comparison to crops in treatments C and D where no earthing was carried out till the middle of July in 1937 and in 1939. In these two years reduction in the number of tillers was about 8 per cent in treatment B where only one earthing was resorted to on 16 June. During 1940 three earthings were completed by the middle of June in treatment A, two in treatment B and one in treatment C, at fortnightly intervals, as a result of which tillering was reduced by 25 to 31 per cent under three and two earthings and by about 6 per cent under one earthing when compared to control or unearthed-up crop. This is contrary to the findings of Subramaniam and Ramiah [1935] at Mandya where light earthing had no adverse effect on tillering, but agrees with the findings in Bihar as stated by Sethi [1940].

(*ii*) *Cane formation.* The significant interference in the tillering capacity is not limited to the young shoots alone but brings about a reduction in the number of canes formed in comparison to the crop where normal earthing is carried out during rains or where the crop is left unearthed.

During 1937-38 a decrease by 3, 6 and 9 per cent was observed in the number of canes formed per acre, respectively, under once, twice and thrice earthed-up crop in comparison to the crop which was not earthed-up. This reduction in the number of canes formed per acre varied from 5 to 14 per cent in 1940-41 and confirmed the observations made during 1937-38. It was in 1939-40 that the number of canes formed in the treated area increased by about 5 per cent compared to the unearthed-up crop. This increase in the number of canes was found to be insignificant on statistical analysis. Besides, it was observed that the average weight of the individual cane sticks, from the earthed-up crop, had slightly increased, and was proportionate with the number of earthings.

(*iii*) *Yield.* An increase in yield from 50 to 100 md. per acre was observed in the earthed-up crop of Co S 70 during 1937-38 and 1939-40. But in 1940-41 when the experiment was repeated with Co S 178, one to two per cent decrease in the yield of sugarcane occurred under three and two earthings, though one earthing resulted in

about 4½ per cent increase over the unearthed-up crop.

(*iv*) *Juice quality.* It has been observed by Sethi, *et al.* [1937] that the percentage of sucrose and purity coefficient in juice slightly decreases on earthing up. This is confirmed from juice analysis carried out at the time of harvest by taking two clumps from each plot and analysing the composite samples from each treatment. It would be observed from Table II, columns 12 and 13, that there is a slight decrease in the per cent sucrose and purity coefficient in the juice analysis data of Co S 70 for 1939-40. It is confirmed in the subsequent year from the juice analysis results of Co S 178, where the decrease in the sucrose percentage is from half to one per cent. The year 1937-38 happened to be rather an abnormal year on account of a very severe attack of pyrilla, as a result of which the crop remained considerably poor in sugar contents, even as late as in April. The unearthed-up crop was poorer still as it had badly lodged.

Summary and conclusions

Light earthing-up, when the crop is young, has been found to be a useful measure in Mysore State as it protects the tender stalks of plants from the ravages of stem borer *A. sticticraspis.* This method of checking the borer damage to sugarcane plants was given a fair trial at Sugarcane Research Station, Muzaffarnagar, during 1937-38, 1939-40 and 1940-41.

Three, two and one earthing commenced from the middle of May and repeated at monthly and fortnightly intervals were compared with the unearthed-up crop. The various effects of early earthing-up on stem borer attack, tillering, cane formation, quality and quantity of the crop, were studied. It was observed that two to three earthings during May and June considerably reduced the borer attack. Tillering and cane formation is lowered but without materially interfering with the yield and quality of cane at harvest.. Two light earthings, one by the end of May and another by the middle of June followed by the final earthing-up during rains, are recommended.

Acknowledgements

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THE ANALYSIS, GRADING AND UTILIZATION OF INDIAN LINTERS

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I. G[illegible]

Introduction

Cotton linters are those short fibres which are left on the seed after the lint has been removed in the ginning operation. These are subsequently extracted by a special process called delinting. These linters are now-a-days used in numerous industries such as the manufacture of artificial silk, insulators, radio panels, non-shatter glass, bottle caps, cellulose acetate and nitrate lacquers, explosives, etc., and thus represent a valuable raw material in the economy of a country. Though linters appeared as an industrial raw material in United States of America about the end of the nineteenth century, production of linters on a commercial scale was unknown in India until very recently when the Indian Central Cotton Committee began to take an interest in the problem. At present a few thousand bales of linters are produced annually in this country, but in the absence of any cellulose industry in India, the producer has to depend on the foreign markets in which he meets with strong competition from the highly organized American linters industry. Consequently only a portion of the total material potentially available is at present recovered, while the remainder is disposed of with the seed and thus represents a clear loss to the country.

Owing to the non-uniform quality of Indian linters, as will be seen from data presented in this report, considerable difficulty has been experienced in disposing of even the present small supply of linters. Therefore, if Indian linters are to be put to their numerous industrial uses within or outside the country, it is necessary that they should be standardized in different grades. Grading would

not only help in finding a reliable market for the raw material, but would pave the way for building up a new industry, namely the chemical cotton industry in this country, which is the starting point for numerous other industries.

Any sample of linters contains a certain quantity of trash associated with it, which is made up of dust, leaf rests, stalk-bits, boll husks, cut and uncut seed, etc. The larger the quantity of this trash or foreign matter, the lower in general is the grade of the sample, though the type or nature of the trash would also influence the grade to some extent. The estimation of the pure cellulose in a commercial sample can be carried out with a high degree of accuracy by means of a kier boiling and bleaching treatment and subsequent analysis, while the amount of trash can be approximately found by passing the sample through a suitable opening and cleaning machinery. The real basic raw material of the cellulose industry, which consumes about two-thirds of the available supply of linters, however, is alpha-cellulose which is prepared from the former by chemical methods. It was, therefore, decided that the alpha-cellulose content of the Indian linters should be ascertained experimentally and that these values should be correlated to the percentage of fibre and percentage of trash as found by mechanical cleaning, as the latter method can be used more conveniently for grading the linters.

In America the method of surface grading is followed for grading linters. Sets of seven standard grades of American linters are prepared by the Department of Agriculture, which are supplied to the purchasers on payment of a fixed sum. One such set of standard grades of American linters was obtained for the Technological Laboratory with a view to comparing Indian linters with the American linters. The results obtained by this method are also discussed in this report and compared with those obtained by the mechanical analysis.

Material. The material to be investigated, viz. linters, belonged to the two seasons, 1938-39 and 1939-40 and was obtained either from the ginning factories or from oil mills, mainly situated in northern India. An attempt was also made to obtain information as regards the variety of seed-cotton, the type of gin in which it was ginned and the type of delinting machine used in recovering the linters so as to correlate, if possible, these various factors. Information was also sought on the cost of production, the railway freight and the price of linters so as to take into account these economic factors, especially in the matter of comparison with the American linters. So far as 1938-39 samples are concerned the information on these various points was far from being complete, but it was more definite as regards 1939-40 samples.

Experimental procedure (A) Analytical and (B) Surface grading

(A) The analytical methods used on linters were (1) mechanical cleaning and (2) chemical treatment.

(1) *Mechanical cleaning.* A sample of linters weighing 50 gm. was passed through the Shirley Analyser and the treatment was repeated on the trash until it ceased to deliver any appreciable quantity of fibre. The clean fibres thus obtained were found to be almost free from any impurities, but their quantity varied considerably according to the amount of trash present in the original sample. It should be stated that during the passage of the sample through the Shirley Analyser some of the very short fibres were lost in the blast and their loss has been designated as the 'invisible loss'. Furthermore, as it was not possible to ascertain the amount of dust in linters by this mechanical treatment, the ash content of the raw linters has also been determined as an index of dust content and has been tabulated along with the results of mechanical analysis.

(2) *Chemical treatment.* A sample of linters weighing about 50 gm. was given, without any mechanical cleaning except the removal of whole seed, an alkali treatment in an autoclave without a stirrer under conditions stated below :

10 per cent caustic soda on the weight of linters—1 : 10 bath ratio.

5 hr. duration of treatment—160° C. temperature.

Prior to alkali treatment the linters were wetted with 1 per cent solution of Lisapol A and the quantity of water retained by them was taken into account while fixing the bath ratio at 1 : 10.

Linters removed from the autoclave were washed clean with water and soured with 1 per cent acetic acid solution for ½ hr., before they were subjected to the bleaching treatment. The conditions of this treatment were kept uniform throughout this investigation. The soured sample was kept for two hours in a calcium hypochlorite solution with about 2 g/l available chlorine. The bath ratio of the linters to bleaching liquor was kept 1 : 20. On completion of bleaching the linters were washed with water, soured for 15 min. in a ½ per cent solution of hydrochloric acid, washed free of the acid and finally dried.

The chemical cotton thus obtained was tested for its alpha-cellulose content according to method described by Doree. The ash content of chemical cotton was also determined as it forms an important criterion of the quality of the material in many industries.

(B) *Surface grading.* The American standards for the year 1939-40 were accepted as the basis for this study. A representative surface was prepared from each sample for comparison with standard American grades and the sample of Indian linters was allotted that particular number of the American grade with which it matched best in general character. In most cases the Indian linters did not match exactly with the American ones in every detail, and consequently it was found necessary to note down the salient points of difference.

II. Results and discussion

The results of the mechanical analysis of Indian linters of two seasons are given in Tables I (*a*) and (*b*).

(*a*) *Discussion of the results of mechanical analysis*

In Tables I (*a*) and I (*b*) the results of mechanical analysis have been given in terms of fibre, trash, invisible loss and for the sake of convenience of comparison the values of ash percentages are also shown. These will now be dealt with individually.

Fibres. The wide variation in the fibre contents of the 1938-39 samples, ranging from 37·5 to 80 per cent show clearly the urgent necessity of standardizing Indian linters. Although the linters of 1939-40 season show a considerable improvement over those of the previous season in this respect, it is certain that further improvement would result from standardizing the Indian linters. The fibre percentage does not represent the total quantity of fibres present in a given sample, as some of the very short ones may be blown off with the air-current, while others may remain in the trash in the form of neps and motes which are not opened up by the Shirley Analyser. For the present, however, the percentage of fibres as given in Tables I (*a*) and I (*b*) is accepted as a useful figure representing the quantity of fibres in each case.

Trash. A glance at the percentage of trash given by the mechanical cleaning will show that our delinting needs considerable improvement. In a number of cases, particularly in the 1938-39 season, the percentage of trash must be regarded as very high, denoting that either through lack of knowledge or care, the linters became adulterated with dust, seed and leaf rests. In fact, it is difficult to understand how leaf rests could find their way to linters to such an extent. Furthermore, both cut and whole seed has been found in several samples of both the seasons which can only be due to carelessness or faulty delinting. Except in this respect, i.e. the presence of cut or whole seed, the linters of 1939-40 season show very considerable improvement over those of the previous season.

The green undeveloped seed which was often found in 1939-40 samples, must also be avoided. It will be shown later that it depresses the quality of chemical cotton by lowering the alpha-cellulose content. The necessity of properly cleaning the seed prior to delinting cannot be too strongly emphasized.

Invisible loss. This is caused mostly by some of the very short fibres being blown off with the air current and to a very small extent by the fine particles of dust escaping along with these short fibres. There is bound to be some fluctuation in the percentage of invisible loss as it would depend upon the quality of linters. It may be noted that the invisible loss is very considerable in case of two samples Nos. 1 and 9 in 1938-39 season and in one sample No. 8 in the following season. These apparently contained more short fibres or fuzz than the others.

The invisible loss was comparatively small for the 1939-40 samples showing thereby that the extremely short fibres or fuzz were not removed from the seed during delinting. It is a controvertible point whether this practice should be encouraged, as it obviously results in a lower yield of linters. In such cases it would perhaps be better to have recourse to two cuts instead of only one and market the produce separately. In any case this problem offers scope especially with regard to the economic factors.

Ash. The determination of ash content of raw linters was undertaken as an index of the amount of dust in them, as the separation of dust from the trash was not possible.

The ash content of raw linters of 1938-39 season fluctuates between 2 and 11·3 per cent. This is a wide range and shows that linters were not carefully handled. In fact, in two cases, viz. Nos. 8 and 12 the ash content is so high that it is difficult to explain it on the grounds of the natural impurities present in linters. Table I (*a*) shows that the high ash content cannot always be attributed to the presence of leaf or seed rests. There are samples which have a very high percentage of trash consisting mainly either of seed rests or leaf rests but give a low ash content, and *vice versa*. Hence, when an abnormally high ash content is found in raw linters, it is generally due to dust and sand particles.

Turning to the 1939-40 samples we find that except in two cases, namely Nos. 9 and 23, the ash content is always below 3 per cent which may be regarded as the maximum permissible limit, as generally speaking our experiments have shown that linters possessing less than 3 per cent ash content give a chemical cotton whose ash content is below 0·12 per cent which is the limit accepted for industrial chemical cotton. The need for

TABLE I (*a*)

Results of mechanical analysis of Indian linters, 1938-39 season

Serial No.	Seed	Station	Saw or Roller gin	Fibres per cent	Trash per cent	Invisible loss per cent	Ash per cent
1	Sind-Hyderabad	Hyderabad, Sind.	..	62·5	15·0	22·5	2·9
2	4F (Punjab)	Punjab	..	75·0	15·0	10·0	2·0
3	285F (N. T.) Sind	Sind	..	72·5	17·5	10·0	2·4
4	285F (Mirpurkhas)	Mirpurkhas (1)	..	65·0	22·5	12·5	3·7
5	,,	,, (2)	..	52·5	37·5	10·0	2·9
6	289F (Punjab)	Punjab	..	80·0	12·5	7·5	3·0
7	,, saw gin	Sargodha	Saw gin	75·0	15·0	10·0	5·2
8	,, roller gin	,,	Roller gin	57·5	32·5	10·0	9·7
9	Mixed roller gin	,,	Saw gin	37·5	47·5	15·0	5·1
10	4F—75 per cent *Desi*—25 per cent	Okara	..	75·0	15·0	10·0	2·4
11	4F—70 per cent *Desi*—50 per cent	,,	..	67·5	20·0	12·5	4·1
12	289F—91 per cent 4F—7 per cent L. S. S.—2 per cent	..	Roller gin	45·0	45·0	10·0	11·3
13	289F (saw gin)	..	Saw gin	60·0	27·5	12·5	3·4
14	4F—76 per cent *Desi*—18 per cent 289F—6 per cent	..	..	57·5	32·5	10·0	4·4
15	289F—91 per cent 4F—7 per cent L. S. S.—2 per cent	..	Saw gin	70·0	20·0	10·0	4·5

TABLE I (*b*)

Results of mechanical analysis of Indian linters 1939-40 season

Serial No.	Seed	Station	Saw or Roller gin	Fibres per cent	Trash per cent	Invisible loss per cent	Ash per cent
1	4F	Khanewal	Saw	81·0	11·6	7·4	2·1
2	,,	Mailsi	Saw	81·2	12·6	6·2	1·7
3A	,,	Vihari	Saw	78·2	14·2	7·6	2·4
3B	289F	,,	Saw	83·0	9·8	7·2	1·6
4	*Desi*—20 per cent P.-A.—80 per cent	Okara	Saw	86·8	8·2	5·0	1·4
5	*Desi*—50 per cent P.-A.—50 per cent	,,	Saw	86·4	6·4	7·2	1·4
6	285F	Hyderabad, Sind.	Saw and Roller mixed	83·8	11·6	4·6	2·3
7	,,	,,	,, ,,	82·4	11·6	6·0	2·2
8	,,	Navsari	..	70·6	14·0	15·4	2·0
9	4F	Burewala	Saw	75·0	18·0	7·0	3·8
10	289F	Sargodha	Saw	82·0	9·4	8·6	2·1
11	*Desi*—30 per cent P.-A.—70 per cent	Okara	Saw	83 0	10·6	6·4	1·5
12	289F	Mianchannu	Saw	82·0	10·6	7·4	2·1
13	4F	Arafwala	Saw	76·4	18·0	5·6	2·5
14	4F	Montogmery	Saw	80·6	13·2	6·2	1·9
15	289F—75 per cent 4F—25 per cent	Mianchannu	Saw	85·6	10·4	4·0	2·6
16	289F	Khanewal	Saw	78·6	14·0	7·4	2·6
17	*Desi*—15 per cent 4F—85 per cent	Lyallpur	Saw	80·8	14·4	4·8	2·1
18	4F	Mianchannu	Saw	90·0	6·4	3·6	1·3
19	4F	Khanewal	Saw	88·0	5·2	6·8	2·2
20	289F	Sargodha	Saw	82·0	10·8	7·2	2·0
21	289F	Mianchannu	Saw	87·2	6·8	6·0	2·2
22	4F	,,	Saw	88·2	6·6	5·2	2·8
23	289F	,,	Roller	67·4	25·6	7·0	6·2

leanliness especially from dust and sand, cannot be sufficiently stressed, as these mpurities are mainly responsible for the high ash content of chemical cotton prepared from linters.

Effect of variety and gin. Taking 1938-39 samples first it will be seen that the results of mechanical analysis vary very considerably even for the same variety. For example, three samples of 285F differ to the extent of about 20 per cent ibre content and four samples of 289F show even a still greater variation. Most probably these differences are due to the degree of care and attention paid to delinting at the various stations.

The type of gin seems to have a very pronounced effect on the quality of linters. For example, Nos. 7 and 8, both belong to 289F and are both delinted at the same station ; yet they gave very different results, showing that saw gin is preferable to roller gin, so far as the quality of linters removed subsequently is concerned. This conclusion is supported by the results pertaining to Nos. 12 and 15 which are mixtures of the same variety of seed in the same proportions, but were ginned in roller and saw gin respectively. We may, therefore, conclude on the basis of these results that the quality of linters is better from a saw-ginned than from roller-ginned seed.

Turning to the 1939-40 samples, it will be noticed that the same type of seed has given very nearly the same quality of linters regardless of the station at which it was delinted. Small variations are of course unavoidable, but on the whole, the results of the eight samples of 4F, six samples of 289F and three samples of 285F are much more concordant and uniform than those observed for the 1938-39 samples. Comparison of the different varieties of seed shows that on the average 4F seed gave linters with slightly higher fibre content and slightly lower trash content than those from 289F or 285F seed among which there was nothing much to choose in this respect. The invisible loss was also lower, on the average, for the linters from the 4F seed than for the other two types of seeds, but the average ash content was lowest for the linters from the 285F seed.

As regards the effect of the type of gin, there is only one instance in which both roller and saw gins had been used with the same seed, viz. 289F. The difference of nearly 20 per cent in the fibre content of the two samples—Nos. 21 and 23—supports the conclusion drawn from the linters of the previous season that saw-ginned seed gives a better quality of linters than the roller-ginned seed.

The types of machines used for delinting the seed were generally speaking either 'Continental' or 'Carvers', the former being somewhat more common than the latter. In one case we came across 'Verner' type of machine while at another place locally made delinting machine seems to have given quite satisfactory results.

Results of the chemical analysis of Indian linters of two seasons are given below in Tables II (*a*) and II (*b*) :

TABLE II (*a*)

Results of chemical analysis of Indian linters 1938-39 season

Serial No.	Chemical cotton per cent	Alpha-cellulose in chemical cotton per cent	Dry alpha-cellulose in air-dry linters per cent	Ash per cent
1	74·0	98·0	67·1	0·08
2	76·0	99·0	69·6	0·07
3	77·0	98·0	69·8	0·12
4	66·0	97·0	59·2	0·14
5	58·0	85·0	45·6	0·15
6	78·0	99·0	71·4	0·29
7	74·0	98·0	67·1	0·37
8	60·0	96·0	53·3	0·41
9	46·0	90·0	38·3	0·24
10	75·0	98·0	68·0	0·09
11	68·0	95·0	59·7	0·41
12	49·0	91·0	41·2	2·12
13	62·0	98·0	56·2	0·28
14	58·0	94·0	50·4	0·13
15	68·0	96·0	60·4	0·16

(*b*) *Discussion of the results of chemical analysis*

The results of the chemical analysis are given in Tables II (*a*) and II (*b*) in terms of the percentages of chemical cotton in linters, of alpha-cellulose in chemical cotton, of dry alpha-cellulose in air-dry linters and of the ash percentage of chemical cotton ; these are dealt with individually below.

Chemical cotton. In case of the 1938-39 samples [Table II (*a*)] the variation in the percentages of chemical cotton is roughly of the same magnitude as shown by the fibre content [Table I(*a*)]. Similarly, the linters of the 1939-40 season [Table II (*b*)] show a much smaller variation in their chemical cotton percentages, which is roughly of the same order as the variation shown by the fibre content of these samples [Table I (*b*)]. This correspondence between the results of two treatments indicates the likelihood of a definite relationship between the two series. It must, however, be remembered that it is not the chemical cotton, but the alpha-cellulose which is regarded as a standard or criterion of quality by the cellulose industry and we shall therefore proceed to consider the results pertaining to alpha-cellulose.

Alpha-cellulose in chemical cotton. The alpha-cellulose content of the chemical cotton obtained from linters of the 1938-39 season was found

TABLE II (*b*)

Results of chemical analysis of Indian linters 1939-40 season

Serial No.	Chemical cotton per cent	Alpha-cellulose in chemical cotton per cent	Dry alpha-cellulose in air-dry linters per cent	Ash per cent
1	76·4	98·2	69·4	0·07
2	78·0	97·7	70·5	0·06
3A	74·2	98·5	67·6	0·07
3B	82·0	98·4	74·6	0·05
4	83·4	98·1	75·7	0·05
5	84·2	98·6	76·8	0·06
6	81·4	98·3	74·0	0·07
7	80·2	98·8	73·3	0·07
8	74·0	98·5	67·4	0·06
9	73·6	97·2	66·2	0·13
10	80·0	98·4	72·8	0·07
11	79·2	96·5	70·7	0·06
12	80·0	97·9	72·4	0·09
13	73·0	98·1	66·2	0·08
14	76·6	97·3	68·9	0·05
15	80·2	96·9	71·5	0·06
16	75·6	97·8	68·4	0·08
17	79·6	98·5	72·5	0·05
18	86·2	99·0	78·9	0·04
19	83·0	97·5	74·8	0·05
20	77·2	98·0	70·0	0·05
21	81·8	98·2	74·3	0·08
22	83·2	98·7	75·9	0·09
23	62·0	98·1	56·3	0·15

to vary from 85 to 99 per cent. A variation of this magnitude is undesirable from the commercial point of view as the cotton generally contains a very small quantity of hemi-cellulose which do not ordinarily exceed 2 per cent. The high percentage of hemi-cellulose in some of the 1938-39 linters can only be attributed to the presence of foreign matter in the form of leaf or seed rests which must have persisted even up to the stage of the chemical cotton.

If we compare Tables I (*a*) and II (*b*) with a view to establishing a relationship, if any, between the alpha-cellulose content of the chemical cotton and the trash percentage present in the original samples, it will be found that up to a trash content of 17·5 per cent the linters yield a chemical cotton with an alpha-cellulose content of not less than 98 per cent which is the permissible minimum for rayon manufacture. But linters having a trash content of 17·5—32·5 per cent yielded chemical cotton with alpha-cellulose content varying from 94 to 98 per cent while the chemical cotton prepared from linters having a still higher trash content, namely from 32·5 to 47·5 per cent possessed alpha-cellulose content varying from 85 to 91 per cent. The only exception to this grouping is No. 13 which in spite of having a trash content of more than 17·5 per cent yielded chemical cotton with 98 per cent alpha-cellulose. This, however, was due to the fact that the sample contained a considerable quantity of seed, which was removed before it was subjected to the chemical treatment.

Turning now to 1939-40 samples we find again that, on the whole, the linters are much superior to those of the previous season as two-thirds of these yielded chemical cotton with alpha-cellulose content up to the industrial standard of 98 per cent or above. Even in the remaining one-third the alpha-cellulose content is not very low, the lowest value being 96 5 per cent.

It is, however, noteworthy that unlike the 1938-39 samples, those of 1939-40 do not show direct relation between trash percentage and alpha-cellulose content while it may be stated in general that linters having low trash percentage will yield a chemical cotton with a high alpha-cellulose content. It must be remembered that it is not always the quantity but also the nature of the impurities present in raw linters which will finally determine the alpha-cellulose content of the chemical cotton from it. Thus, whereas a fairly high trash content in the form of leaf, stalk bits, etc., would be removed in the chemical process and may not therefore affect appreciably the alpha-cellulose content of the chemical cotton, a relatively low trash content in the form of undeveloped or crushed seed may persist in the chemical treatment, and may lower the alpha-cellulose content beyond the industrially permissible limit.

Dry alpha-cellulose in air-dry linters. The dry alpha-cellulose content of the air-dry linters is the real indicator of the quality of linters from the industrial point of view. This has been calculated for both the seasons and the values are given in Tables II (*a*) and II (*b*).

Ash content of chemical cotton. As may be seen from Table II (*a*), the ash content of the chemical cotton obtained from linters of 1938-39 season varied from 0·07—0·41 per cent with the exception of No. 12 of which the ash content was found to be as high as 2·12 per cent. While discussing ash content of raw linters, the abnormally high values were attributed to the presence of dust particles present in the samples. This explanation is actually corroborated by the following experiment.

Chemical cotton No. 12 which gave an abnormally high ash content of 2·12 per cent was shaken for half an hour in water over a fine sieve for removing small particles of dust. By this simple treatment the ash content came down to 0·59 per cent, i.e. nearly one-fourth of the original value. Three further similar treatments brought down the ash content of the same sample to 0·35 per cent proving definitely that the high

percentage of ash was due to the presence of dust particles embedded in the linters which could not be removed by the ordinary treatment given to all the samples but required a special treatment.

The tolerance for ash content is 0·12 per cent in case of industrial chemical cotton, while the ash content of the chemical cotton obtained from a number of samples was found to be higher than 0·12 per cent [Table II (*a*)]. As shown above, it can be brought down by suitable adjustments in processing in the form of either a preliminary mechanical cleaning or a series of rifflers preceding the final washing. Such treatment, however, would add to the cost of manufacture of chemical cotton, and, therefore, the best course would be to improve delinting so as to avoid admixture of dust with linters.

The ash content of the chemical cotton of 1939-40 linters is found to be satisfactory in all cases except only two, namely Nos. 9 and 23.

While the percentage of trash gives no indication as to the amount of dust present in the sample, the ash content of raw linters and that of chemical cotton prepared from it are associated with one another. In view of this observation the ash content of raw linters may advantageously be introduced as a factor in the grading of linters.

Wax. As some samples of linters (of the 1938-39 season) appeared to contain more oil or fat than the rest, it was decided to treat three selected samples with benzine in a Soxhlet apparatus for six hours for fat extraction. The results are stated below :

Serial No.	Percentage of benzene extract
5	0·76
7	0·64
9	0·88

In each case the fat and wax content is somewhat higher than the highest found in Indian cottons. Its presence, however, is not harmful as the fat would be saponified during the alkali treatment. To test this point the wax content of the chemical cotton of No. 9 which gave the highest wax content in raw state was determined and found to be 0·12 per cent which is below the tolerance limit of 0·34 per cent, showing that most of the original fat and wax in the sample had been removed by the normal chemical treatment. The position, however, would be quite different if a sample were contaminated with mineral oil, which cannot be saponified by the alkali treatment, and would therefore remain in the chemical cotton possibly rendering it unsuitable for industrial use. Contamination with mineral oils must therefore be avoided.

Surface grading. The results of surface grading of linters, which it must be pointed out, have been tried for the first time in India are given in Tables III (*a*) and III (*b*).

TABLE III (*a*)

Results of the surface grading of Indian linters 1938-39 season

Serial No.	Matching U. S. Grade No. in		Colour	Foreign matter			Remarks
	Character	Colour		Leaf	Stalk	Seed	
1	5	..	Yellowish white	....	....	....	Very small quantity of cotton fibre was seen distributed throughout the sample
2	2	..	Greyish white	Some	Some	....	....
3	2	2	....	Fair amount of small brown leaf	.....	.....	....
4	(Between 4 and 5)		....	Fairly large quantity of large brown leaf	Some	Small quantity of broken seed	....
5	4	4	....	Fair amount of large leaf	Some	Plenty of cut seed	The foreign matter was sticking to and uniformly distributed throughout the sample
6	(Between 1 and 2)		....	Some brown and some black leaf	....	....	...
7	2	2	....	Fair amount of black peppery leaf	Some	....	....
8	4	4	....	Some black and brown leaf	....	Small quantity of seed	Contained a small quantity of cotton fibre
9	(4—5)	..	Greyish white	Large amount	Some	Large amount of seed	....
10	2	..	" .... "	Some peppery leaf	....	....	....
11	(Between 3 and 4)		....	Some black peppery leaf	Some	Some seed	....
12	(Between 4 and 5)		....	Fair amount of brown leaf	Some	Large amount of crushed seed	....
13	2	2	....	Some brown leaf	....	Large amount of uncrushed seed	.....
14	3	..	Greyish white	Fairly large quantity	Fairly large quantity	. ..	The red leaf which the sample contained appears to be foreign in its origin
15	A 1 / B (Between 2 and 4)	1	....	Large brown leaf	Some	....	This sample was a heterogenous mixture of 3 possibly 4 grades

TABLE III (*b*)

Results of surface grading of Indian linters 1939-40 season

Serial No.	Matching U. S. Grade No. in		Colour	Foreign matter			Remarks
	Character	Colour		Leaf	Stalk	Seed	
1	3	..	Greyish white	Some small brown and peppery leaf	Some	.....	It also contained boll-rests
2	2—3	..	,, ,,	,, ,, ,,	Few	Undeveloped green seed	....
3A	4	..	Greyish	Small	Small	Fair amount of undeveloped seed	It also contained some boll husks
I	3	3	.....	Small black peppery leaf	....	Few	....
3B II	1	1	.....	.....	.....	Large amount .	Also some black seeds (Egyptian?)
4	2	..	Greyish white	Small	.....	Some whole seed	....
5	3	..	,, ,,	Fair quantity of small black leaf	.....	Small quantity	....
6	3	..	Dirty yellow	Fair quantity of brown leaf	.....	.....	Some cotton fibres distributed throughout
7	3	..	Very dirty yellow	Large quantity	.....	Some crushed seed	....
8	6—7	6—7	Dirty brown	....	....	....	....
9	2	..	Greyish white	Fair amount	.....	.....	Also boll-rests
10	3	3	.....	Some	....	....	....
11	2	..	Greyish white	Slight	.....	Fair quantity .	....
12	1	..	Whiter than U. S. Grade No. 1	Some	....	Small quantity of undeveloped seed	....
13	2	..	Whiter than U. S. Grade No. 2	Slight	.....	Large quantity of whole seed	Some of the seeds were in clusters
14	2	..	Greyish white	Large quantity of peppery leaf	....	Some crushed seed	....
15	1—2	1—2	.....	Some leaf, also peppery	.....	Fairly large quantity of crushed seed	....
16	2—3	2—3	....	Black peppery leaf	....	Slight crushed seed	....
17	3	..	Greyish white	Fairly large amount of brown and peppery leaf	....	Some crushed seed	....
18	1	..	Whiter than U. S. Grade No. 1	Fair amount of dark brown leaf	....	Some undeveloped seed	....
19	2	..	Greyish white	Some dark brown and black peppery leaf	....	Slight	....
20	2	..	Whiter than U. S. Grade No. 2	Small quantity of brown and black peppery leaf	....	Some whole seed	....
21	1	1	....	Small	.....	Small quantity of whole crushed seed	....
22	2	..	Whiter than U. S. Grade No. 2	Small quantity of black peppery leaf	.....	Very small quantity of whole and crushed seed	....
23	3	..	Whiter than U. S. Grade No. 3	Plenty	Plenty	Plenty cut and whole	....

(c) *Discussion of the results of surface grading*

In connection with this grading it is important to bear in mind two points. In the first place it is customary to take into account staple, foreign matter, colour and character indicating the grade of a sample. In the present work, however, only the staple and character of Indian linters have contributed towards the fixing of the grade, the other two factors, viz. the colour and foreign matter having been noted down separately. Secondly, no effort has been made to give a final grade to any sample. Only in case of character a definite grade number is given, but the final grade must emerge out of it after the other factors especially colour and amount and type of foreign matter are given due consideration. In the case of colour, it is not yet established to what extent 'dirty yellow', 'dirty brown' or greyish white', etc., should influence the grade number while as regards foreign matter, it will be seen that this important factor has been simply noted down as observed. In the present state of affairs this procedure was inevitable, but when Indian standards of grades are prepared, these factors will have to be taken into account, and then it would be possible to fix closely the grade of a sample by comparison against the standards. Even with the limitations noted above, the results of surface grading are very interesting and are discussed below.

Staple and character. We note from Table III (a) that five samples out of 15 matched the American grade No. 2, one was slightly better, while of the remaining eight were inferior, matching grade Nos. 3, 4 and 5. One sample—No. 15—was peculiar in the sense that it was a clear mixture of two types of linters, one of which was superior to the other. None of the 15 samples matched the American grade No. 1, while none of them was below No. 5 in grade. Thus, the limits, in terms of the American grades, for these 15 samples were set by No. 2 and No. 5, roughly one-third matching No. 2 and the remaining being of inferior grades. Turning to the 1939-40 samples we find that three out of the 24 samples were of such superior quality as to match the American grade No. 1 in character, one was slightly lower (between 1 and 2), 8 samples matched grade No. 2, two were slightly lower (between 2 and 3), seven samples matched grade No. 3, while only two samples were below grade No. 3. Among the latter only one sample was of real inferior quality lying between grade Nos. 6 and 7, while the other matched grade No. 4. Here again one sample—No. 3B—was found to be a mixture of two types, one of which was definitely superior to the other. Thus, if we ignore only two samples Nos. 3A and 8 the limits for these samples are set by grade Nos. 1 and 3, the majority of them matching either No. 2 or No. 3. These results bring out clearly the improvement in the grade of the 1939-40 samples as compared with those of the earlier season, of course, with respect to staple and character.

Colour. The colour of Indian linters was found in most cases to be different from that of the American standard which were 'reddish brown', the colour being practically absent in standard No. 1 and successively increasing in intensity towards the last standard No. 7. On the other hand, some of the Indian linters were white, whiter than even American standard No. 1, others were greyish, white to grey, while yet others were more or less brownish in colour.

It is interesting to note that as a rule the 4F seed gave linters which were greyish white in colour in general and white or grey in a few cases. In case of mixtures wherever the 4F seed predominates, the greyish white colour was to be noticed. On the other hand the linters from the 289F seed showed in most cases a distinct brownish colour though in a few cases it was white or dirty brown. On the whole the colour of the linters obtained from the 289F seed resembled the colour of the American linters, while the linters from the 285F seed resembled those of 289F seed, though the former showed a yellowish tinge which lent a rather dirty appearance to the linters.

Foreign matter. This is sub-divided into three heads—leaf, stalk and seed—and the quantity visually observed in each case is also set down in terms of 'fair', 'large', 'fairly large' 'small', 'slight', etc.

It is interesting to note in this connection the relation existing between the kind and quantity of foreign matter present in the raw linters and the alpha-cellulose content of the chemical cotton obtained from them. The general conclusions which are applicable to linters of both the seasons, are given below.

(*a*) So long as the quantity of leaf or stalk was 'small' or in 'fair amount' and the sample did not contain either crushed or undeveloped seed in an appreciable quantity the chemical cotton obtained from it gave an alpha-cellulose content of at least 98 per cent.

(*b*) If, however, the sample of linters contained 'large' or 'fairly large' quantity of leaf or an appreciable quantity of undeveloped seed or even a small quantity of crushed or whole seed which is not removed by mechanical means, the chemical cotton obtained from it gave an alpha-cellulose content of less than 98 per cent. Thus, the presence in linters of seed, particularly crushed seed is very detrimental to the quality of the

TABLE IV

Comparison of some results of mechanical analysis and chemical analysis, 1938-39 season

Serial No.	Fibres mechanically analysed— Per cent A	Chemical cotton chemically analysed— Per cent B	Dry alpha-cellulose in air-dry linters— Per cent C	Difference (A—B) D	Difference (A—C) E
1	62·5	74·0	67·1	—11·5	—4·6
2	75·0	76·0	69·6	—1·0	5·4
3	72·5	77·0	69·8	—4·5	2·7
4	65·0	66·0	59·2	—1·0	5·8
5	52·5	58·0	45·6	—5·5	6·9
6	80·0	78·0	71·4	2·0	8·6
7	75·0	74·0	67·1	1·0	7·9
8	57·5	60·0	53·3	—2·5	4·2
9	37·5	46·0	38·3	—8·5	—0·8
10	75·0	75·0	68·0	0·0	7·0
11	67·5	68·0	59·7	—0·5	7·8
12	45·0	49·0	41·2	—4·0	3·8
13	60·0	62·0	56·2	—2·0	3·8
14	57·5	58·0	50·4	—0·4	7·1
15	70·0	68·0	60·4	2·0	9·6
Total	952·5	989·0	877·3	—36·5	75·2
Mean	63·5 per cent	65·9 per cent	58·5 per cent	—2·4	5·01
Coeff. of variation	19·0 per cent	15·4 per cent	18·5 per cent	156·9 per cent	75·0 per cent

chemical cotton obtained from them, while the presence of leaf in linters is relatively less deleterious.

III. COMPARISON OF THE RESULTS OF MECHANICAL AND CHEMICAL ANALYSES

A comparison of the values given in columns A and B in Table IV shows that in most cases the yield of chemical cotton is actually higher than that of the clean fibre as shown by the values in column D. This apparent discrepancy is due to two factors : (1) some of the short fibres present in a sample are blown off as invisible loss in the Shirley Analyser, while in the chemical treatment they contribute towards the yield of the chemical cotton and (2) in the Shirley Analyser some neps and motes are lost as trash while these too give their quota in the chemical treatment. Since the alpha-cellulose content, in which the useless hemi-celluloses are left out of consideration is very important, its values are reproduced in column C, while column E gives the difference between it and the fibre content.

The coefficients of variation of the differences have been worked out in each case. It will be seen that the coefficient of variation of the differences between the fibre content and chemical cotton is more than double of that obtained for the differences between fibre content and alpha-cellulose, showing that alpha-cellulose bears a closer relation to the fibre content than chemical cotton. Nevertheless its high value of 75 per cent should serve as a warning against accepting the fibre-content of mechanical analysis as a true index of the alpha-content of a sample of linters.

In view of the fact that the invisible loss sustained in the Shirley Analyser is almost wholly of short fibres or fuzz which, as explained above, make their contribution in the chemical treatment, an attempt was made to find a relationship by adding the invisible loss to the quantity of fibres actually separated by the Shirley Analyser. The results obtained are given in Table V.

It is very interesting to note that the coefficient of variation of the differences between the fibre content and the alpha-cellulose, which was 75 per cent (Table IV), has, by the inclusion of the invisible loss, come down to 13·1 per cent for the 1938-39 season samples. Similarly for the 1939-40 samples the coefficient of variation of the differences between the total fibre content and the alpha-cellulose content works out at 10·1 per cent

TABLE V

Differences between the total fibre and alpha-cellulose contents in linter samples

Serial No.	Fibre per cent F	Invisible loss per cent f	Total fibre per cent $F+f$	Dry alpha-cellulose in air-dry linters α	Difference—Total fibre minus alpha-cellulose $F+f-\alpha$
			1938-39		
1	62·5	22·5	85·0	67·1	17·9
2	75·0	10·0	85·0	69·6	15·4
3	72·5	10·0	82·5	69·8	12·7
4	65·0	12·5	77·5	59·2	18·3
5	52·5	10·0	62·5	45·6	16·9
6	80·0	7·5	87·5	71·4	16·1
7	75·0	10·0	85·0	67·1	17·9
8	57·5	10·0	67·5	53·3	14·2
9	37·5	15·0	52·5	38·3	14·2
10	75·0	10·0	85·0	68·0	17·0
11	67·5	12·5	80·0	59·7	20·3
12	45·0	10·0	55·0	41·2	13·8
13	60·0	12·5	72·5	56·2	16·3
14	57·5	10·0	67·5	50·4	17·1
15	70·0	10·0	80·0	60·4	19·6
				Coefficient of variation :	13·1 per cent
			1939-40		
1	81·0	7·4	88·4	69·4	19·0
2	81·2	6·2	87·4	70·5	16·9
3A	78·2	7·6	85·8	67·6	18·2
3B	83·0	7·2	90·2	74·6	15·6
4	86·8	5·0	91·8	75·7	16·1
5	86·4	7·2	93·6	76·8	16·8
6	83·8	4·6	88·4	74·0	14·4
7	82·4	6·0	88·4	73·3	15·1
8	70·6	15·4	86·0	67·4	18·6
9	75·0	7·0	82·0	66·2	15·8
10	82·0	8·6	90·0	72·8	17·8
11	83·0	6·4	89·4	70·7	18·7
12	82·0	7·4	89·4	72·4	17·0
13	76·4	5·6	82·0	66·2	15·8
14	80·6	6·2	86·8	68·9	17·9
15	85·6	4·0	89·6	71·5	18·1
16	78·6	7·4	86·0	68·4	17·6
17	80·8	4·8	85·6	72·5	13·1
18	90·0	3·6	93·6	78·9	14·7
19	88·0	6·8	94·8	74·8	20 0
20	82·0	7·2	89·2	70·0	19·2
21	87·2	6·0	93·2	74·3	18·9
22	88·2	5·2	93·4	75·9	17·5
23	67·4	7·0	74·4	56·3	18·1
				Coefficient of variation :	10·1 per cent
Total (39 readings)		.....		.....	658·6
Mean (39 readings)		.....		.....	16·9
Coefficeint of variation per cent		.....		.....	11·3

which is even better than that obtained for 1938-39 samples. The mean value of this difference for the two seasons comes out to be 16·9.

The small values of the coefficient of variation and the general run of the data relating to linters of widely varying qualities belonging to two different seasons led us to suspect that a general relationship exists between the total fibre-content and the alpha-cellulose content of sample of Indian linters. In order to find this relationship a linear regression of the form $y=a+bx$, where y is the alpha-cellulose content (α), x is the *total* fibre content ($F + f$), and a and b are constants, was fitted to the 39 observations given in Table V, and its equation was found to be:

$$y=0\cdot9404\ x-11\cdot9271 \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The difference of the coefficient (0·9404) of the total fibre content (x) from unity is 0·0596 with a standard error of 0·029 showing that it is not significantly different from unity; while the standard error of the constant, a (11·9271), is 2·420 which is thus significantly different from zero. Thus, the equation (1) may be replaced by

$$\alpha=F+f-K \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where K is a constant and has a value of 16·9.

This formula is not only very interesting but highly useful, as it enables one to predict, with a fair degree of accuracy, the alpha-cellulose content of a sample of Indian linters without actually performing the chemical test on it but merely from the results of mechanical analysis which is comparatively quicker and less elaborate. In order to judge the validity and limits of usefulness of this formula, the values of alpha-cellulose content of all the samples of linters of the two seasons were calculated and compared with the experimental values. Table VI gives the distribution of differences between the calculated and the predicted values.

TABLE VI

Difference (per cent)	No. of value	
0—1·0	8	
1·1—2·0	12	
2·1—3·0	10	
3·1—4·0	2	Average 2·3 per cent
4·1—5·0	2	
5·1—6·0	4	
6·1—7·0	1	
	39	

It will be seen that for 20 samples out of 39 the difference between the actual and the calculated values of the alpha-cellulose content is less than 2 per cent, while only in five cases it exceeds 5 per cent. The average difference between the actual and the calculated values for both seasons is only 2·3 per cent. This agreement must be regarded as very satisfactory and the formula may be used confidently for estimating the alpha-cellulose content of Indian linters.

IV. Comparison of the Surface Grading Method with Mechanical Analysis

The method generally adopted in America for grading linters takes into account the following four points (1) staple, (2) foreign matter, (3) colour and (4) character. The significance of each of the factors may be briefly explained as follows:

Staple. The exact significance of this term is somewhat different from what is generally understood in the case of cotton. In case of linters it refers to the aggregate impression or estimation of the different blends of long and short fibres present in a sample, and is determined chiefly by the relative proportion of each class of fibre.

Foreign matter. It generally consists of stalks, leaves, motes, hull particles, dirt and any other matter adhering to the linters. In preparing the standards, allowance is made for specified quantities of foreign matter in each grade. All samples having more foreign matter than that specified in a standard are classed 'off grade'.

Colour. Olive and buff are the colours referred to in American official grades, but generally those who deal in linters call them 'green' and 'cream'.

Character. This property is rather difficult to define in terms of physical attributes. It refers to the section of the cotton belt, or the area in which the seed cotton, from which the linters are obtained, is grown.

In United States of America linters have been standardized in seven grades. The delinting process may be carried out in two ways. The seed may be delinted in one single operation removing the long as well as the short fibres together, the linters thus obtained being designated 'Mill-run'. Alternatively, the seed may be delinted in two successive operations, the first one removing mostly the long hairs called 'first cut' and the second one removing the remaining fibres on the seed, called 'second cut'. The 'first cut' generally gives grades Nos. 1, 2 and 3 while the 'second cut' delivers grades Nos. 5, 6 and 7. The proportion of the first cut to the second cut is roughly 1 : 4 by weight. Very often the seed is delinted at once and the 'mill run' thus obtained is generally classified in grades Nos. 3, 4 and 5.

First cuts: Cuts ranging from 20 to 50 lb. per ton of seed have generally become known as first cuts or first cut linters.

Mill runs: Cuts ranging from about 35 to 100 or more per ton of seed are known as mill runs or mill run linters.

Second cuts: After a first cutting, especially if not over 50 lb. per ton of seed have been removed by the first delinting, the seeds are frequently passed through the delinting machine a second time. The linters thus recovered are known as second cuts. The total quantity of linters recovered ranges from about 30 lb. to as high as 200 lb. per ton of seed.

In India the processes of recovering the linters have not yet become standardized, while no standards are available against which the samples offered in the market may be matched and valued. It is hoped that this investigation, in which a new method of grading linters has been worked out, will lead to the preparation of commercial standards. It will be remembered that 39 samples of Indian linters belonging to two seasons were subjected to mechanical and chemical treatments, the grades being graded as best as possible under the circumstances by the surface grading method, and the results of the two methods have been compared. Since this method is offered to serve as a basis for the preparation of standard grades suitable for Indian linters, it was felt that it would be instructive to examine the American grades by this method. For this purpose, American standard grades of linters which were obtained from U. S. A., were subjected to mechanical and chemical treatments and the results obtained are given in Tables VII (*a*) and VII (*b*).

TABLE VII (*a*)

Mechanical analysis

Grade No.	Per cent fibre	Per cent trash	Per cent invisible loss	Per cent ash	Per cent dry alpha-cellulose—calculated ($F+f-K=\alpha$ where $K=16\cdot9$)
1	93·8	3·2	3·0	1·04	80·0
2	88·8	4·6	6·6	1·09	78·6
3	84·8	6·8	9·4	1·11	77·4
4	77·0	9·6	13·4	1·12	73·6
5	69·2	11·0	19·8	1·16	72·2
6	64·0	13·8	22·2	1·42	69·4
7	60·8	15·6	23·6	1·62	67·6

TABLE VII (*b*)

Chemical analysis

Grade No.	Per cent chemical cotton	Per cent alpha-cellulose in chemical cotton	Per cent ash	(Experimental) Per cent dry alpha-cellulose in air dry linters
1	87·8	99·5	0·04	80·8
2	85·3	99·1	0·05	78·2
3	84·2	98·7	0·07	76·9
4	81·8	98·9	0·07	74·8
5	78·4	99·1	0·07	71·9
6	75·9	96·7	0·07	67·9
7	74·8	96·6	0·08	66·8

The most interesting feature of Tables VII (*a*) and VII (*b*) is the very close agreement which has been found to exist between the calculated and the experimental values of the dry alpha-cellulose content as given in the last columns of the two tables. This establishes the validity and indicates the usefulness of the formula $F+f-K=\alpha$, which enables us to grade linters with accuracy and speed. A new method of grading linters, based on this formula, is suggested below:

A representative sample weighing about 100 gm. of the linters, which are to be graded, should be passed through the Shirley Analyser, and the trash should be passed again and again until a measurable quantity of fibres cannot be recovered from it. The separated fibres and the trash should be weighed carefully, and the invisible loss should be ascertained by deducting these two from the original weight of the sample. By substituting the actual values for F (separated fibres) and f (the invisible loss) in the formula $F+f-K=\alpha$, K being a constant equal to 16·9, the dry alpha-cellulose content of the sample should be obtained. Table VIII should then be used to decide the grade in which the sample should be placed.

TABLE VIII

In case of per cent α cellulose (dry) in air dry linters	To be classed in grade No.
80 and above	1
76 and 80	2
72 and 76	3
68 and 72	4
64 and 68	5
60 and 64	6
56 and 60	7

In case the alpha-cellulose content is less than 56 per cent, the sample should be regarded 'off grade'. It will be noticed that the lower limit of α-cellulose suggested above is 56 per cent as against 66 per cent found for the American standard grades. It should, however, be noted, in this connection, that whereas the mechanical analysis tests have been made on the commercial samples of Indian linters obtained from the delinting factories, these tests have been carried out on the American standard grades which are carefully prepared by the U. S. A. Department of Agriculture. Therefore, the two sets of samples and their results are not strictly comparable, and the results of tests on American standard grades can only be taken as a rough guide for fixing tentative standards for Indian linters. These results would have been comparable if similar tests could have been carried out on commercial samples of American linters, which would have revealed how far, in actual practice, they deviate from their standard grades. This was, however, not possible owing to the extraordinary conditions prevailing at present. Until such tests have been carried out on American as well as a larger number of commercial Indian linters, the standards suggested here should be regarded as tentative, which should serve as a working basis, but which should be modified, if necessary, in the light of further experience.

Since it may not be possible in each case to pass a sample of linters offered in the market through the Shirley Analyser, it is desirable to prepare, with the help of this method, boxes of standard grades from typical Indian linters, so that a large number of samples may be matched against them, as is done in the case of cotton.

We shall now see to what extent this metho of grading samples of linters would give th purchaser useful information regarding th quality of the material. According to the Amer can method of grading, each grade gives th purchaser some information about staple, foreig matter, colour and character. The last tw items, however, do not appear to be so im portant as the first two items, especially whe the linters are to be transformed into chemic cotton. Whether a sample of linters looks 'gre or 'brown' and whether it has been obtained fro a Sind-American or Punjab-American seed woul make practically no difference to the qualit of cellulose obtained from it. Thus, leavin these two items, i.e. colour and character, out account in arriving at a method for gradin linters, we find that the staple and the amoun of foreign matter in a sample are the most im portant factors in determining its grade.

The method proposed above must therefo satisfy the purchaser regarding staple and foreig matter present in each grade. If, instead giving information regarding the quantity foreign matter present in a sample, it were po sible to give the exact amount of alpha-cellulos available in that sample, it would be a definit improvement over the old method. The stap also plays an important role and should be a counted for in the proposed method of gradin the alpha-cellulose content being independe of the staple. With a view to finding out simple and reliable method of expressing th staple of a sample of linters, it was essenti to know the staple of the standard America grades of linters, although this work was labour ous and time-consuming. The group-lengt distribution in percentage by weight of th standard grades is given in Table IX.

TABLE IX

Distribution of group-lengths in U. S. grades (1939-40)

Group length	1st grade	2nd grade	3rd grade	4th grade	5th grade	6th grade	7th grad
1/16 in. & less	1·4	5·2	9·8	10·2	19·4	22·3	23·0
1/8 in.	16·3	34·5	35·1	36·3	54·0	55·6	65·6
2/8 in.	11·5	17·0	17·5	14·1	13·8	16·1	8·7
3/8 in.	8·1	7·8	10·5	4·6	4·4	4·5	0·7
4/8 in.	10·7	8·9	3·6	8·8	3·4	..	0·9
5/8 in.	13·7	11·8	5·2	9·0	3·1	..	1·1
6/8 in.	14·7	7·1	6·3	7·5	..	..	..
7/8 in.	11·1	4·9	5·5	3·9	..	1·5	..
1 in.	7·3	2·8	5·2	4·4	..	..	..
1 1/8 in.	2·8	..	..	1·2	1·9	..	..
1 2/8 in.	2·4	..	1·3	..	..	..	..

A glance at Table IX shows that the percentage of the short group-lengths, particularly $\frac{1}{16}$ in. and $\frac{1}{8}$ in., goes on steadily increasing, while that of the remaining (long) group-lengths goes on generally decreasing to vanishing point, as the grade of the linters falls, although here and there a stray long fibre might be found even in the lower grades.

Furthermore it will be observed from Table IX that the seven grades may be resolved into three groups. The first group consists of grades No. 1 and 2, which possess a much larger percentage of long fibres ($> \frac{1}{8}$ in.) than of the short ones ($< \frac{1}{8}$ in.). Grades No. 3 and 4 form the second group in which the long and the short fibres are present in almost equal proportions. The third group is formed by grades No. 5, 6 and 7 wherein the proportion of short fibres is much larger than that of the long ones. It is interesting to remember in this connection that generally the 1st and 2nd grades are obtained from the 'first cut', 3rd and 4th grades from 'mill-run' and 5th, 6th and 7th grades from the 'second cut'.

This group-length determination of linters, though interesting, does not lead us any farther towards the solution of the problem of evolving a quick method of grading, because it requires so much time that it must be ruled out as a practical method. If, however, attention is centered on the shortest group length ($\frac{1}{16}$ in.) only, on account of its being particularly representative of the grades, and if it is assumed that the proportion of various group lengths in each grade is more or loss constant, as it should be, the solution of the problem draws nearer. This line of approach is supported by a comparison of the invisible loss in the Shirley Analyser and the percentage of the fibres possessing a group length of $\frac{1}{16}$ in., which are practically identical. The small differences observed between the two are within sampling error, and we may therefore conclude that the invisible loss (per cent) in the mechanical analysis is equal to the percentage of $\frac{1}{16}$ in. group length fibres in a sample of linters, this group length, on its part, being representative of the grade. In this way it is possible to indicate the staple of the sample with the help of the invisible loss without actually determining it. Thus, mechanical analysis will not only furnish information on the total amount of foreign matter present in a sample, but also on its staple.

The new method proposed for Indian linters is based on the tentative specifications given in Table X.

If we apply the criteria implied in this method of grading to the samples of Indian linters, which formed the subject of investigation, we obtain results given in Table XI, which also shows the results of surface grading for purposes of comparison.

TABLE X

Per cent dry alpha-cellulose in air-dry linters	Per cent invisible loss	Grade to be allotted	Per cent invisible loss in the 3 groups
80 and above	0—5	1	0-8 'First cut'
76 and 80	5—8	2	
72 and 76	8—11	3	8-16 'Mill-run'
68 and 72	11—16	4	
64 and 68	16—21	5	16 and more 'second cut'
60 and 64	21—23	6	
56 and 60	23 & more	7	
Below 56	..	off	

TABLE XI

Comparison of the results of surface grading with those obtained by the proposed method

1938-39 Season

Serial No.	Surface grading—Grade No.	Proposed grading		
		On α—basic (Calc.)	On f—basis	Final grade
1	5	4	6	5
2	2	4	3	4
3	2	5	3	4
4	4—5	6	4	5
5	4	Off	3	Off
6	1—2	4	2	3
7	2	4	3	4
8	4	Off	3	Off
9	4—5	,,	4	,,
10	2	4	3	4
11	3—4	6	4	5
12	4—5	Off	3	Off
13	2	7	4	5—6
14	3	Off	3	Off
15	A: 1 B:2—4	6	3	4—5

N. B.—In fixing the final grade attention is paid both to the alpha-cellulose content and the invisible loss (per cent) of the sample. When the difference between the grades as indicated by the two methods is only one, the grade indicated by the alpha-cellulose content is taken as

the final grade. Where the difference between the two grades is 2, the grade indicated by the alpha-cellulose content is raised or lowered, as the case may be, by one grade. Similarly, for larger differences. Where a sample is shown to be off-grade by the alpha-cellulose content, it is regarded as off-grade in the final evaluation, as the alpha-cellulose content is given the predominant place.

1939-40 Season

Serial No.	Surface grading — Grade No.	Proposed grading		
		On α — basis (Calc.)	On f— basis	Final grade
1	3	4	2	3
2	2—3	4	2	3
3A	4	4	2	3
3B	A 3 / B 1	3	2	3
4	2	3	1	2
5	3	2	2	2
6	3	4	1	2—3
7	3	3	2	3
8	6—7	4	4	4
9	2	5	2	3—4
10	3	3	3	3
11	2	3	2	3
12	1	3	2	3
13	2	5	2	3—4
14	2	4	2	3
15	1—2	3	1	2
16	2—3	4	2	3
17	3	4	1	2—3
18	1	2	1	2
19	2	2	2	2
20	2	3	2	3
21	1	2	2	2
22	2	2	2	2
23	3	7	2	5

It will be seen that in the case of 1938-39 samples there is considerable difference in the grades obtained by the surface grading method and the proposed method. This is mainly due to the fact that the amount of the foreign matter cannot be properly estimated in the surface grading method, while it is accurately given by the chemical method. This difference is less conspicuous in 1939-40 season, as these linters contained less foreign matter than the 1938-39 samples. If the results of the surface grading method are compared with those obtained by consideration of the invisible loss alone, it will be seen that the two agree fairly well in both seasons, showing that this method attaches greater importance to the staple of the sample. For final grading, however, both staple and foreign matter have to be considered jointly, with greater emphasis on the latter in view of the fact that it indicates the quantity of the available cellulose.

The fairly satisfactory agreement between the grades obtained by the two methods in case of linters of 1939-40 season, which were comparatively cleaner, shows that the surface grading method can be applied to linters, provided they are fairly clean and the grader lays proper emphasis on the quantity of foreign matter present in the linters in fixing the final grade.

It will be noticed from the invisible loss (per cent) of the linters that all samples of the 1938-39 season, with the exception of No. 1, which is a second cut, are 'mill-run'. In 1939-40 season all samples except No. 8, which is a 'mill-run', are 'first cut' as confirmed by the producers. It shows that there is nothing really wrong with the delinting industry in this country, except that here and there a few whole or crushed seeds find their way into the sample. A more serious fault, shown by this work, is the presence of large quantity of foreign matter in the linters, which, in actual practice, would detract from their grade and utility to the consuming industries. It is gratifying to note, in this connection, that the 1939-40 linters show a distinct improvement over those of the previous year in the matter of cleanliness and grade. Since the Indian linter industry is very young, it is reasonable to hope that this improvement noticed in 1939-40 will continue, and that within a short time the linters produced in India will be equal to those produced elsewhere in respect of grade and quality. In the meantime, effort should be made to remove this defect, which is responsible for placing 5 out of 15 samples of 1938-39 in the 'off grade' class, and for the lowering of the grade of several samples by one or even two grades in 1939-40 season.

Turning to the choice of one of the two methods stated above, it is to be noted that the surface grading method is liable to subjective errors, and is therefore at best an approximation. The proportion of the fibre to fuzz and the amount of various impurities present in the sample cannot be estimated with the eye as exactly as with a machine, the difficulty becoming greater in the lower grades. In the mechanical method, on the other hand, the percentage of fibres and trash is obtained by actual measurements. Once the results of the mechanical analysis are available, they may be substituted in the formula $F+f-K=\alpha$ to get the alpha-cellulose content of the sample, the staple being disclosed by the invisible loss. The mechanical method will naturally take more time than the surface grading method, but the former is preferable to the latter in view of the higher accuracy of the results obtained, where a Shirley Analyser is easily accessible.

It is true that in U. S. A., the largest producer of linters, the trade relies mainly on the surface

grading method. But there are indications to show that they are not satisfied with the existing state of affairs and have drawn up an extensive scheme of research on linters to be worked out in every detail, right from the effect of soil to chemical cleaning, in their newly-built regional research laboratories. Since the results of the investigation carried out here have pointed the way to a reliable and accurate method of grading linters which is capable of classifying them according to their alpha-cellulose content, we should take full advantage of these results and adopt this accurate method of grading linters wherever suitable testing facilities are availabe. If, however, such testing facilities are not readily accessible, then the trade may adopt the alternative method of comparing a given sample of linters with standard grades prepared by a recognized organization. It should, however, be borne in mind that in the final analysis and for accurate work only methods of chemical and mechanical testing are capable of giving reliable results. Such methods of grading would ensure the supply of linters of known and uniform quality, which would help in securing wide and permanent markets both at home and abroad, and would thus assist in building up the chemical cotton and the allied industries on sound lines.

V. Economic aspects

We shall now discuss some of the economic aspects of the production of linters in India and the manufacture of chemical cotton from them. The first question, which we propose to consider, is to what extent Indian linters can be produced commercially for export purposes and for the manufacture of chemical cotton in the country. In this connection it is important to bear in mind that the production of linters in the Indian oil mills and delinting factories is a very recent development, and, therefore, the present output of a few thousand bales, which are offered every year for sale in the market, is not a true index of the potential supply of this material in the country. In order to form an approximate idea of the potential supply inquiries were made from the Departments of Agriculture of all the cotton growing provinces and States in India as to the quantity of seed available in each province which could be used for delinting purposes. From the information supplied it would appear that, at a very moderate estimate, the total quantity of fuzzy seed, which may be used for delinting, available in the country is nearly 9 lakhs of tons. In order to estimate the total quantity of linters recoverable from the seed it is necessary to know the yield of linters per ton of seed. Inquiries were addressed to several oil mills and factories, where delinting is being carried out at present, and the figures kindly supplied by them are shown in column 8 of Table XII. Though the individual figures vary, as might be expected on account of differences in the type of seed, delinting machinery, etc., the average value calculated from their replies came to 45 lb. per ton, representing a yield of 2 per cent on the weight of the seed. On the basis of this average figure the potential annual supply of linters in India is estimated to be about 80,000 bales of 400 lb. each. In order to arrive at a more correct estimate, it would be necessary to conduct a survey with the two-fold object of finding out on the one hand the quantity of fuzzy seed grown in each area and on the other hand the amount of fuzz present on each type of seed. We may mention here that attempts were also made to find out the total quantity of linters that are being actually produced in the country at present, but unfortunately no reliable data could be collected.

The potential supply of 80,000 bales of linters of 400 lb. each is not very large as compared with the American supply which in 1938-39 stood at 1,116,000 bales of 500 lb. each, being equivalent to nearly 1,400,000 bales of 400 lb. In making a comparison between the Indian and the American linters and in drawing conclusions regarding the future of the former industry, it is necessary to bear in mind certain salient points of difference. In the first place it must be remembered that the American cotton crop is, on the average, nearly $2\frac{1}{2}$ times as large as the Indian cotton crop so that a very much larger quantity of seed is available in America for delinting purposes. Secondly, the bulk of the American seed is of the fuzzy type which can be delinted and which gives a fairly good yield of linters, while many varieties of the Indian seed are either very nearly naked or have a very small quantity of fuzz at their apical ends. The main types of fuzzy seeds available in India are P.A. 289F, 289F/43, 289F/K 25, Cambodia Co2, Upland Gadag, Sind-American, etc. while such types as Surti, L.S.S., Westerns, Broach *desi*, Bengals, etc. are of the non-fuzzy type. Thirdly, the production of linters in America has increased steadily owing to the demand for this material in U. S. A. and the world markets as it forms the raw material for numerous industries. When nearly 40 years ago the linters were first produced in the U. S. A., their total production amounted to only 100,000 bales. In a few years the production went up very considerably until in 1914-15 it stood at over 800,000 bales. Since then the production of linters in U. S. A. is shown in Table XIII which gives the production of cotton and linters in America from 1914-15 to 1938-39.

It is interesting to note that whereas the proportion of linters to cotton was only 5·2 per

TABLE XII

Particulars regarding Indian linters of 1939-40 season

Serial No.	Variety of seed	Place where delinted	Gin-Saw or Roller	First Cut, Second Cut or Mill	Price per md. of 82 2/7 lb.	Delinting machine used	Linters recovered per ton of seed	Matching U.S.A. Grade No.		Colour	Foreign matter
								Character	Colour		
1	4F	Khanewal	Saw	First cut	Rs. 5 to 6 locally and loose	Continental	45 lb. to 67 lb.	3	...	Greyish-white	Small brown and peppery leaf some stalk, also some boll rests
2	4F	Mailsi	,,	,,	Rs. 5/8/- ,,	Carvers	,,	2—3	...	,,	Some brown and peppery leaf, few stalks and some undeveloped green seed
3A	4F	Vihari	,,	,,	,, ,,	,,	,,	4	...	Greyish	Small amount of leaf and stalk but fair amount of undeveloped seed; also some boll husks.
3B	289F	,,	,,	,,	Rs. 6/- ,,	,,	,,	I 3 II 1	3 1	... I ... II	Small amount of leaf and a few seeds.
4	20% *Desi* 80% P.A.	Okara	,,	...	...	,,	45 lb.	2	...	Greyish white	Large amount of seed, some black ones (Egyptian?). Small quantity of seed and some whole seed.
5	50% *Desi* 50% P.A.	,,	,,	...	...	,,	,,	3	...	,,	Fair quantity of small leaf also small quantity of seed.
6	285F	Hyderabad Sind	Saw and Roller	First cut	Rs. 5/- f.o.r.	,,	,,	3	...	Dirty yellow	Fair quantity of brown leaf, some cotton fibres distributed throughout the sample.
7	285F	,,	Mixed	,,	...	,,	,,	3	...	Very dirty yellow	Large quantity of leaf and some crushed seed.
8	285F	Navsari	...	Mill run	...	,,	45 lb. to 56 lb.	6—7	...	Dirty brown	...
9	4F	Burewala	Saw	First cut	Rs. 6/- to Rs. 8/-	Continental	18-17 lb.	2	...	Greyish white	Fair amount of leaf, also some whole and crushed seed—some boll rests also
10	289F	Sargodha	,,	,,	Rs. 5/10/-	,,	60 lb.	3	3	...	Some leaf and some whole and crushed seed
11	30% *Desi* 70% PA.	Okara	,,	,,	...	Varner	40 lb.	2	...	Greyish white	Slight leaf and a fair quantity of seed
12	289F	Mian-channu	,,	,,	...	Continental	55 lb.	1	...	Whiter than U.S. Grade No. 1	Some leaf and a small quantity of undeveloped seed
13	4F	Arafwala	,,	,,	...	,,	25 to 28 lb.	2	...	Whiter than U.S. Grade No. 2	Slight leaf and a large quantity of whole seed, some of them in clusters
14	4F	Montgomery	,,	...	Rs. 8/- f.o.r.	,,	13 lb.	2	...	Greyish white	Large quantity of peppery leaf and some crushed seed
15	75% 289F 25% 4F	Mian-channu	,,	...	...	,,	54 lb.	1—2	1—2	...	Some leaf and a fairly large quantity of crushed seed.
16	289F	Khanewal	,,	First cut	Rs. 7/4/- including pressing charges	,,	27 lb.	2—3	2—3	...	Black peppery leaf and slight crushed seed
17	85% 4F 15% *Desi*	Lyallpur	,,	,,	Rs. 8/-	,,	About 10 lb.	3	...	Greyish white	Fairly large amount of leaf and some crusehd seed
18	4F	Mian-channu	,,	,,	Rs. 7/-	,,	41 lb.	1	...	Whiter than U.S. Grade No. 1	Fair amount of leaf and some undeveloped seed.
19	4F	Khanewal	,,	,,	...	,,	17 lb.	2	...	Greyish white	Some leaf and slight sand
20	289F	Sargodha	,,	,,	Rs. 4/8/-	Carvers	54 lb.	2	...	Whiter than U.S. Grade No. 2	Small quantity of seed and some whole seed
21	289F	Mian-channu	,,	,,	1st and 2nd quality linters at Rs. 6	Country (self made) delinting machine	42 lb.	1	1	...	Small quantity of leaf, as well as whole and crushed seed
22	4F	,,	,,	,,	,,	,,	22 lb.	2	...	Whiter than U.S. Grade No. 2	Small quantity of leaf, and very small quantity of whole and crushed seed
23	289F	,,	Roller	,,	3rd quality at Rs. 2/-	,,	36 lb.	3	...	Whiter than U.S. Grade No. 3	Plenty of leaf, stalk and seed

TABLE XIII

roduction of cotton and linters in America during 1914-15 to 1938-39

Season	(In 1,000 bales running) Cotton	Linters	Percentage of linters on cotton production
14-15 .	15,906	832	5.2
19-20 .	11,326	595	5.3
24-25 .	13,639	858	6·3
29-30 .	14,548	1,038	7·1
30-31 .	13,756	824	6·0
31-32 .	16,629	876	5·3
32-33 .	12,710	741	5·9
33-34 .	12,664	801	6·3
34-35 .	9,472	805	8·5
35-36 .	10,420	876	8·4
36-37 .	12,141	1,127	9·2
37-38 .	18,252	1,471	8·0
38-39 .	11,623	1,116	9·6
39-40 .	11,928	..	..

nt in 1914-15 in 1938-39 it had risen to 9·6 per nt. The principal causes for this increase e: (*a*) steadily increasing demand, (*b*) improvement in methods of delinting and (*c*) the production, in later years, of 'mill run' and 'second t' linters in addition to the first cut linters. We all consider this last point in some detail. ost of the linters which are at present produced India belong to the quality commonly known 'first cut', while in America they belong to ee qualities namely 'first cut', 'mill run' and cond cut'. The definition of these three qualis according to U. S. Department of Agriculture* f has been given earlier in these pages.

The distribution of the American linters in se three qualities since 1933-37 is shown in ble XIV from which it will be seen that only out 20 per cent of the total quantity of linters the U. S. A. are of the first cut quality, about per cent are mill run, while about 50 per nt belong to the second cut quality.

TABLE XIV

stribution of American linters In bales in the three ualities, First Cuts, Mill Runs and Second Cuts

ason	First Cuts	Mill Runs	Secnd Cuts	Total
33-34	1,42,166	2,68,609	3,89,751	8,00,526
34-35	1,56,772	2,57,934	3,90,377	8,05,083
35-36	1,88,968	2,59,469	4,27,778	8,76,215
36-37	2,74,944	3,18,310	5,33,619	11,26,873

*U. S. Department of Agriculture Miscellaneous Publiion No. 242, May 1936

The average yield of the mill run linters in U. S. A. is 3·2 per cent of the weight of the seed as against 1·6 per cent for the first cut, while the average yield of the second cut is 4·5 per cent. Thus, if the mill run and second cut linters are also recovered in India as is done in America, the total quantity of linters available in India would be very much greater than what it comes into the market at present. Taking all these factors into consideration, we feel confident in stating that when sufficient demand has been built up for Indian linters either for consumption within the country or for export purposes, a very nuch larger supply than is seen at present in the market will be available.

We shall next consider the question as to what proportion of this potential supply of linters would be available for purposes of export and what proportion would be available for the manufacture of chemical cotton in India. In the U. S. A. the linters are divided into seven grades according to the length, colour, character and amount of trash. The grade 1 linters, which have a good proportion of fibres which can be spun, are used for spinning low grade yarns and for the manufacture of mats and fleece-lined products. Grades 2, 3 and 4, which have larger proportions of short fibres, are used for making mattresses, pillows, cushions, felts, etc. while grades 5, 6 and 7 which are sometimes referred to as the 'chemical grades' are generally used for the manufacture of chemical cotton. The distribution of linters in the different grades in U. S. A. will be seen from Table XV from which it will be noticed that the bulk of the linters fall in the grades 3-6, while comparatively smaller proportions conform to grades 1 and 2 on the one hand and grade 7 on the other.

We may mention here that in general the first cut linters give rise to grades 1 and 2, the mill run to grades 3 and 4 and the second cut to grades 5, 6 and 7. This classification, however, should not be regarded as rigid, as, for example, it is quite possible that a first cut sample may conform to grade 3 or a mill run sample to grade 5 depending upon such factors as colour, amount of trash, etc. In India the grading of linters on a systematic basis has not been carried out, and it is, therefore, not possible to give similar figures showing the distribution of Indian linters in the various grades. The surface grading which was done in the course of this work showed that in 1939-40 the bulk of the samples conformed to American grades 2, 3 and 4 ; but this cannot be taken as a true indication of the state of affairs in the future when in addition to the first cut linters both mill run and second cut linters will also be recovered from the Indian seeds. We may, theefore, assume that a large proportion of the Indian linters,

TABLE XV

Production of linters in U. S. A.—distribution of grades

Season	(In bales)							
	Grade No. 1	Grade No. 2	Grade No. 3	Grade No. 4	Grade No. 5	Grade No. 6	Grade No. 7	Total
1933-34	20,196	1,69,052	90,496	89,642	1,73,504	2,49,931	7,705	8,00,526
1934-35	15,844	1,13,714	1,29,996	96,204	1,43,141	2,73,058	33,126	8,05,083
1935-36	14,655	1,09,227	1,43,782	1,09,740	1,55,387	3,11,909	31,515	8,76,215
1936-37	37,458	1,58,393	1,56,249	1,81,669	1,98,260	3,64,642	30,202	11,26,873
1937-38	..	..	..	..	..	..	..	14,71,000
1938-39	..	..	..	..	..	..	..	11,16,000

when the full potential supply is forthcoming, would be available for the manufacture of chemical cotton, while the best grades among them may be used in making mattresses, cushions, pillows, etc.

It is interesting to note, in this connection, that in U. S. A. in the 11 months ending 30 June 1939, 777,000 bales of linters were consumed within the country, while 193,000 bales were exported to foreign countries in the same period. Of the linters consumed within the country, some 400,000 bales were accounted for by those industries which use chemical cotton as their basic material, while the balance must have been consumed in the manufacture of other articles. In the 11 months, preceding 30 June 1940, these figures had increased to 1,070,000 bales for consumption within the States and 305,000 bales for exports to foreign countries, showing the large and profitable trade built up by the U. S. A. from a raw material which until recently has been completely ignored in India.

We may here consider the point whether India should seek to develop a large export trade for her linters or should endeavour to lay greater emphasis upon the development of chemical cotton industry. We are of the opinion that the latter course is more desirable for the following reasons: Firstly, it will promote the establishment of several industries in which chemical cotton is used, and as we have stated elsewhere these industries form a very large group, whose development will stimulate the consumption of other raw materials. Secondly, if the chemical cotton is prepared in India and exported abroad, the monetary return will be greater than that realized for linters. It is true that the different industries using chemical cotton lay down their special requirements in regard to the grade and quality of the material, and the chemical cotton manufactured for each industry will have to conform to these specifications but this is not a difficult matter and the demands of the consuming industries can be easily satisfied with the help of a small Laboratory.

We will next consider the question as to what extent the Indian linters conform to the American standard grades and to what extent they were defective. The full answers to these questions have been given in this report earlier. We may briefly mention here that the quality of linters of the two seasons, 1938-39 and 1939-40 was found to vary considerably, and therefore the same answer cannot be given with regard to linters of these two seasons. The linters of 1938-39 were, on the whole, of a much poorer quality than those of 1939-40, which showed noteworthy improvement both in grade and colour over those of the previous season. The linters of 1938-39 season conform mostly to American grades 4, 5 and 6, while those of the 1939-40 season conform mostly to the American grades 2, 3 and 4. As has been explained in the report, this comparison between the Indian linters and the American grades must be regarded as of a very general nature as there were important differences between the two in regard of colour and the type and quantity of trash present in them. The colour of the American grades ranged from creamy white to brownish red, while that of the Indian linters was mostly greyish white or dirty grey. The differences in the type and quantity of trash present in them were even more remarkable. The trash in the Indian linters, which in some cases was present in considerable quantities, consisted of cut and whole seed, immature seed or motes, boll rests, leaf bits both large and peppery, and dirt and sand. On the other hand the American standard grades were conspicuously free from seed and the trash consisted mostly of fine seed-coat bits, small leaf and dirt. As has been pointed out in the report, it is not always an easy matter to remove fine particles of sand and dirt, which adhere to the linter in the washing process, and, therefore, it thi

pe of trash persists in large quantities in the lian linters, it is likely to result in high ash ntent of the chemical cotton which would make unacceptable to several industries. Similarly, e presence of cut and whole seeds would bring out an appreciable reduction in the yield of emical cotton from a given quantity of linters, ereby depressing their market value. Consequently, if the Indian linters are presented in the arket in a state of reasonable freedom from cut d whole seed and dirt and sand particles, they uld conform more nearly to the American ndard grades and would be taken up more adily and at higher prices by the consuming dustries or the exporters. It is gratifying note in this connection that the linters of the 39-40 season already show good improvement these respects, and we hope that this improvent will be maintained in the future. The fferences in colour are comparatively unimportt as they would disappear in the bleaching ocess to which the chemical cotton is normally bjected.

We will next consider the questions of cost production of linters per lb. and the ice per lb. free on rail at the main centres India. As regards the cost of production quiries were made from a number of factories India which are producing linters but many them expressed their inability to give this formation. Three factories, however, very adly furnished information on this point. Acrding to two of them the cost of production linters in India is about one anna per lb. about Rs. 5 per md. of linters, while cording to the third factory the cost of production is 6·44 pies per lb. or Rs. 2-12 per t. These figures show fair variation and is interesting to note that the linters of which e cost of production is given as Rs. 2-12 per t. were judged, in surface grading, as 'dirty llow' or 'very dirty yellow' and were found contain either fair quantity of brown leaf large quantity of leaf and some crushed seed. aking these factors into account, we are of the inion that a cost of production of 11 to 12 es may be taken as reasonable provided the nters are produced in a fairly clean state.

One of the firms which gave the cost production as one anna per lb. very kindly pplied the following interesting details. Acrding to this firm the cost of production is ade up of (1) power, (2) labour, (3) reduction weight of the resulting cotton seed, and (4) epreciation and interest on machinery. The st of treating the seed to one cut is about one nna per maund, while the resulting loss in eight is about 3½ lb. The value of this loss in weight is 10½ pies which, added to the working costs gives one anna a lb. or about Rs. 5 per md. as the cost of production. In the case of certain types of seed no premium is obtained for delinted seeds, but in the case of other types of seeds, e.g. P.A. 4F a premium of 1½ to 2 annas per md. is obtained for the delinted seed which largely compensates for the cost of treatment in the case of such seed. This cost does not take into account the cost of baling the linters which is about Rs. 2-8 per 5 md. bales or 1·2 pies per lb. of linters.

As regards the price per lb. free on rail at the main centres in India, this would depend, apart from the quality of linters, upon such factors as the demand and available supply at any given time, the distance from the point of production, the price of short staple cotton, the special uses such as the manufacture of gun cotton, explosives, etc. to which, in times of emergency, the linters may be put. The price of linters, therefore, may fluctuate within fairly wide limits owing to these economic factors. This will be seen by the course of prices of American linters between 1930-31 and 1936-37 which are reproduced in Table XVI. The prices of the Indian linters are not available for a number of seasons owing to the infancy of this industry in India, and we are therefore unable to consider their trend in the past few seasons. As regards the samples considered in this report, the prices for the 1938-39 samples were not available in most cases, but we were more fortunate in regard to the 1939-40 samples for which the data were supplied and is given in column 6 of Table XII. It will be noticed that the prices of these samples of linters ranged from Rs. 4-8 to Rs. 8 per md. with the exception of one sample which was priced as low as Rs. 2 per md. the majority of the linters being offered at about Rs. 6 per md. We would naturally expect that the samples which conformed to the higher American grades were offered at relatively higher prices while those which matched the inferior standard grades were offered at lower prices. This is found to be the case in general, but in some cases we came across quite interesting exceptions. For example, sample No. 20 which matched the American standard grade No. 2 was offered at Rs. 4-8 per md. while sample No. 3a which matched the American standard grade No. 4 was offered at Rs. 5-8 per md. These apparent anomalies may partly be due to the different quantities of trash associated with these samples, those having a larger amount of trash being naturally valued at a lower rate than the cleaner ones, but they may also be due to some extent at least to the fact that no systematic grading of Indian linters has yet been carried

out. The individual sellers, therefore, offer their linters partly on the basis of their cost of production which, as we have seen above, may vary considerably, and partly with an eye to the speedy disposal of their produce. Thus, the price obtained by them may not, in all cases, bear an exact relationship to the quality of the material.

We will next endeavour to compare the prices of the Indian linters with those of the American linters. Such a comparison is neither very easy nor reliable in the present state of our knowledge on account of the following reasons. The grading of American linters has been done on a sound and businesslike basis, and a set of standards is prepared each year which reflects truly the character, grade and colour of the bulk of the linters produced in U.S.A. Thus, any sample of the American linters, which is offered in the market, can be readily matched against these standard grades, and its price can be easily fixed in terms of the basic price of the particular grade which lies nearest to it. The Indian linters, however, cannot be readily matched against the American standards because of important differences both in colour and the type and quantity of trash present in them. Thus, it would be quite possible that a sample of Indian linters may conform in general appearance to one of the American standard grades, but may contain larger quantities of crushed or whole seed or sand and dirt, which would certainly detract from its value. Furthermore, in fixing the American standards of linters some regard is paid, especially in the superior grades, to their staple length. In the Indian linters, however, this characteristic has not so far received any serious attention. These important differences between the Indian linters and the American standard grades render an exact comparison between them rather difficult, but if these differences are borne in mind, we may make a general comparison. The average prices of the American grades of linters for the eight seasons 1929-30 to 1936-37 are given in Table XVII.

TABLE XVI

Average prices per lb. in cents

Year	Grade						
	1	2	3	4	5	6	7
1930-31	4·29	3·59	2·98	2·05	1·63	1·24	1·01
1931-32	3·03	2·52	1·93	1·31	1·04	0·83	0·66
1932-33	2·97	2·52	1·98	1·52	1·24	1·04	0·85
1933-34	5·45	5·10	4·51	3·93	3·57	3·25	3·06
1934-35	6·34	5·71	5·18	4·65	4·28	4·00	3·76
1935-36	6·08	5·49	5·01	4·42	3·94	3·43	2·92
1936-37	6·32	5·80	5·25	4·64	4·18	3·79	3·29

TABLE XVII

Price of American linters

Grade No.	Price in rupees per md.	Price in dollars per md.
	Rs. as. ps.	
1	13 13 8	4·16
2	12 4 10	3·69
3	10 9 3	3·18
4	8 13 8	2·65
5	7 13 6	2.36
6	6 12 6	2.03
7	5 14 11	1·78

Referring to Table III we observe that majority of the samples of Indian linters conform, at least in general character, to the American grades 2 and 3, except that the Indian linters contained larger quantities of trash in the form of leaf, crushed and whole seed, boll rests, etc. as will be seen from the last column in Table XII in which the nature and amount of these impurities are described briefly. On referring to Table XVII again, we notice that the average prices of the American standard grades Nos. 2 and 3 were Rs. 12-4-10 and Rs. 10-9-3 per md. respectively. If we compare these with the prices of the Indian linters, namely Rs. 6 to Rs. 7 per md., we see that the latter have been offered in the market at much lower prices than those obtaining for the American linters of approximately corresponding grades. Part of this difference is no doubt due to the larger quantities of trash present in the Indian linters, but even after making due allowance for this factor, we cannot help feeling that owing to lack of proper grading, inadequate demand in the country

and the absence of suitable marketing facilities, the Indian linters have been sold at lower prices than they should have fetched according to their grade and quality. We are of the opinion that if the delinting of Indian seeds is improved, as can be done readily, so as to reduce the quantity of trash in the linters, and if a proper set of standard grades is prepared each year and the linters are graded as is done in America, the producers would get much better prices for their raw material.

We will finally consider briefly the machinery which is used in the production of linters. The seed cotton is, of course, ginned either on a roller gin or a saw gin and the seed thus obtained, which contains from 1.5 to 4 per cent of linters, is then passed through a delinting machine. From the information which has kindly been supplied by the factories, it appears that three types of delinting machines are being used at present in India. These are the Continental, Carvers and Verner machines. In addition, one of the factories used a country made delinting machine, and it is interesting to note that the quality of the linters produced on this machine was not very inferior to that of the linters produced with the help of the imported machines. In most cases the Indian factories produced the quality of linters known as first cut and therefore their yields per ton of seed were rather small as compared with the American yields. It is, however, highly probable that the machines used by them can be employed with suitable changes in settings, etc. for producing either mill run or second cut linters as well, though there appears to be some prejudice, as stated by one of the factories, against treating the seed to a second cut on the grounds that such linters have a bad colour and that their production involves greater wear and tear of the machinery.

VI. Conclusions

An attempt has been made to grade 39 samples of Indian linters belonging to the 1938-39 and 1939-40 seasons by three different methods, with a view to evolving a quick and reliable method of grading Indian linters. These methods were (*a*) mechanical analysis, (*b*) chemical analysis and (*c*) surface grading.

The Indian linters of the 1938-39 season showed a fair amount of variation in their quality, some of them containing appreciable quantities of trash in the form of leaf, stalk or seed, the last of them being whole, crushed or undeveloped. The linters of the 1939-40 season show distinct improvement over those of the preceding year in respect of grade and quality, and this feature constitutes a hopeful sign for the future of the chemical cotton industry in India.

A comparison of the results of the mechanical and chemical treatments has shown the existence of a relationship between the fibre content and the percentage of chemical cotton in a sample. This relationship improved by substituting dry alpha-cellulose for the chemical cotton. A further improvement resulted from substituting total fibre content of the sample, i.e. the recovered fibres plus the short fibres or fuzz lost in the form of invisible loss in the formula. The relationship, as finally obtained, between the total fibre content and the dry alpha-cellulose of a sample is as follows :

$$F + f - K = \alpha$$

Where F is the fibre separated by the Shirley Analyser, f is the percentage of fibres below $\frac{1}{16}$ in. given by the invisible loss, K is a constant being equal to 16·9 and α, the dry alpha-cellulose content of the air dry linters.

The average difference between the values of alpha-cellulose content actually obtained by experiments and those calculated with the help of the formula was found to be only 2·3 per cent.

The validity of the formula was also tested by determining, on the one hand, the dry alpha-cellulose content of American Standard Grades of linters, and, on the other, by calculating it with the help of the formula. A close agreement was observed between the two sets of values.

It was found by actual determination of the mean length of fibres in different group lengths in the standard linters that the $\frac{1}{16}$ in. group length represents very closely the invisible loss in the Shirley Analyser. Thus, the mechanical analysis gives an indication of the staple of the sample, as the percentage of fibres having length less than $\frac{1}{16}$ in. goes on diminishing steadily as the staple of the sample increases from grade 7 to grade 1.

A new method based on the mechanical analysis is suggested for grading linters which is capable of giving reliable information as regards the alpha-cellulose content and the staple of a given sample.

The results of the surface grading method have been compared with those obtained by the proposed method. The causes for the observed differences are discussed, and it is pointed out that these serve to emphasize the desirability, even the necessity, of adopting the proposed method for grading linters where testing facilities are available, in preference to the surface grading method.

The economic aspects of the production of linters of different grades in India have been considered. It is estimated that a potential supply of some 80,000 bales of linters of 400 lb.

each already exists in the country, but in order to get at a more correct figure, the need for a properly conducted survey is stressed. It is surmised that a large proportion of this supply would be available for the manufacture of chemical cotton, while the best grades among the Indian linters may be used for stuffing mattresses, cushions, pillows, etc. It is recommended that every effort should be made to develop the chemical cotton industry and the allied industries within the country rather than to export the raw linters to foreign countries.

The cost of production of linters in India in normal times has been investigated and is estimated to be about one anna per lb., though it must vary with such factors as (*a*) cost of power, (*b*) labour charges, (*c*) reduction in weight of the resulting cotton seed, etc. The price actully realized by the linters bore only a general relationship to their quality, as, in some cases, it was affected considerably by (*a*) their cost of production and (*b*) the desire for a speedy disposal. On comparing these prices with those usually offered for American linters of the corresponding grades, it is concluded that the Indian linters have generally been sold at rather low prices. It is suggested that if the trash percentage in the Indian linters could be reduced by improving the delinting methods, Indian linters would fetch higher prices than they did in the 1938-39 and 1939-40 seasons.

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APRICOT SEED CAKE AS A NITROGENOUS MANURE

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(With three text-figures)

Wild apricot (*Prunus armeniaca* Linn., vernacular *Zardalu*) trees grow abundantly on an extensive area in the Simla Hills. Their fruits are consumed. The seeds contain oil, which is used in cooking, burning, toilet creams, and certain pharmaceutical preparations. The oil is obtained by pressing the kernels from the pits, which are separated from the fruits of *Prunus armeniaca* in large quantities in the manufacture of dried apricots. The kernels constitute about 20 per cent of the pits and contain from 40 to 45 per cent of oil. The cake left after extracting the seeds for oil is neither utilized as a cattle-food owing to its bitter taste, nor does it find an alternative application as a manure. It is burnt as a fuel only. The chemical examination of the cake by the method of Warth and Ko Ko Gyi [1918] revealed the presence of 0.057 per cent of hydrocyanic acid, which is high enough to prove fatal to the cattle, when fed. The content of hydrocyanic acid may be attributed to the presence of some cyanogenetic compound like glucoside in the cake. It is well known that glucosides are widely distributed in the plant kingdom and the first products of their hydrolysis in the soil are glucose, aromatic compounds, and hydrocyanic acid.

The cake however contains a good amount of nitrogen (6·7 per cent), besides a fair proportion of phosphate P_2O_5 (1·49 per cent) and potash K_2O (1·09 per cent). Its waste as a fuel is therefore an economic loss to agriculture, especially in its relation to the supply of nitrogen for proper crop production.

With a view to find out its possible utilization as a suitable nitrogenous manure, the enquiry has resolved itself into two distinct divisions, viz.

(1) the biochemical study of its nitrogen transformation in the soil, and

(2) the determination of its efficiency as a nitrogenous manure.

I. Biochemical study of nitrogen transformation in the soil of apricot cake

It is essential to know at the first instance how much of the nitrogen contained in the apricot seed cake can be converted into available forms, before evaluating its efficiency for crop growth in a soil. In order to do this, the cake was subjected to a study of its nitrogen transformation in the laboratory from the biochemical point of view in three different types of soil, viz. (1) a highly calcareous Pusa soil belonging to the trans-Gangetic alluvium, (2) a non-calcareous

Kalianpur soil near Cawnpore, United Provinces, and (3) a hill soil from Solon near Simla Hills. The mechanical and the partial chemical composition of these soils are given in Table I in order to give some idea of their water relationship, aeration, and mineralization of organic matter, etc.

TABLE I

Mechanical and partial chemical composition of Pusa, Kalianpur and Solon soils

Constituents per cent	Pusa soil	Kalianpur soil	Solon soil
I. *Mechanical composition*			
Clay	5·62	12·14	19·96
Silt	23·68	24·80	34·48
Very fine sand	47·37	28·44	18·98
Other sands	23·33	34·62	26·58
II. *Chemical composition*			
Organic matter	2·05	0·72	4·34
Carbon	0·46	0·42	2·52
Nitrogen	0·315	0·072	0·17
Carbon/Nitrogen ratio	14·06	5·80	14·80
Calcium carbonate	35·00	0·50	6·40
*p*H	8·29	7·63	8·19
Water-holding capacity	48·00	52·64	50·10

Forty milligrammes of nitrogen in the form of cake were applied per 100 gm. of air-dry soil and 16 per cent of moisture was maintained throughout the experiments. The incubation was carried out at the ordinary temperature which varied between 29° and 33°C. in the case of Pusa and Kalianpur soils, and between 21° and 31°C. in the case of Solon soils. Periodically samples of soil were drawn and ammonia, nitrite, and nitrate determined in them,—ammonia by the aeration method of Matthews [1920], nitrite and nitrate by the colorimetric methods with sulphanilic acid and α-napthylamine, and with phenoldisulphonic acid respectively. Controls were run simultaneously side by side in the same soils without any application of the cake. While calculating the availability of the cake with respect to different forms of nitrogen as given in the following tables, due allowance was made by subtracting the corresponding values of available nitrogen formed in the controls under identical experimental conditions. The results for Pusa, Kalianpur, and Solon soils are set forth in Tables II and III.

From the data presented in Tables II and III it is evident that 63 and 60 per cent of nitrogen contained in the apricot seed cake have been transformed into available forms by 8 weeks' incubation in Pusa and Kalianpur soils respectively, and 54 and 58 per cent nitrogen of the original and the fat-free cake respectively in Solon soil by about 7 weeks' incubation. These amounts represent the maximum limit of transformation under the experimental conditions as further incubation does not seem to increase

TABLE II

Nitrogen changes of apricot seed cake in Pusa and Kalianpur soils

Number of days incubated	Cake in Pusa soil				Cake in Kalianpur soil			
	Mg. N as NH_3	Mg. N as NO_2	Mg. N as NO_3	Totals	Mg. N as NH_3	Mg. N as NO_2	Mg. N as NO_3	Totals
Nil	0·40	Nil	—0·36	0·04	0·32	Nil	—0·27	0·05
7	15·68	—0·03	—0·36	15·29	6·96	1·39	—1·80	6·55
10	17·76	—0·01	—2·16	15·59	3·04	1·05	4·66	8·75
14	20·24	0·02	—0·72	19·54	1·04	0·07	16·56	17·67
17	21·36	0·05	—1·08	20·33	0·72	0·04	16·74	17·50
21	21·44	0·26	—0·78	20·92	0·32	0·01	17·82	18·15
25	20·24	0·74	—1·44	19·54	0·32	Trace	20·52	20·84
31	15·76	1·57	2·98	20·31	0·24	,,	20·88	21·12
35	13·04	0·82	8·28	22·14	0·32	,,	20·88	21·20
42	10·00	0·01	11·88	21·89	0·32	,,	22·14	22·46
49	7·52	Trace	14·40	21·92	0·16	,,	23·40	23·56
56	6·24	,,	18·72	24·96	0·32	,,	23·76	24·08
70	5·04	,,	18·82	23·86	0·08	,,	23·40	23·48
81	4·80	,,	18·72	23·52	0·24	,,	23·04	23·28
100	4·64	,,	19·26	23·90	0·08	,,	23·04	23·12

TABLE III

Nitrogen changes of apricot seed cake in Solon soil

Number of days incubated	Original cake in Solon soil				Fat-free cake in Solon soil			
	Mg. N as NH_3	Mg. N as NO_2	Mg. N as NO_3	Totals	Mg. N as NH_3	Mg. N as NO_2	Mg. N as NO_3	Totals
Nil	0·08	—0·01	—0·18	—0·11	Nil	—0·01	—0·18	—0·19
3	5·28	0·09	—1·26	4·11	9·04	0·12	—1·17	7·99
5	9·12	0·32	—0·36	9·08	12·40	0·39	0·50	13·29
7	7·04	0·65	3·96	11·65	8·72	0·70	5·76	15·18
10	0·64	0·03	15·52	16·19	0·96	0·02	20·38	21·36
14	0·24	Nil	16·66	16·90	0·24	Nil	20·62	20·86
21	Nil	,,	19·08	19·08	Nil	,,	20·80	20·80
28	,,	,,	19·35	19·35	,,	,,	21·87	21·87
45	,,	,,	21·60	21·60	,,	,,	23·04	23·04
55	,,	,,	21·24	21·24	,,	,,	23·40	23·40
70	,,	,,	21·24	21·24	,,	,,	23·04	23·04
84	,,	,,	21·42	21·42	,,	,,	22·70	22·70
98	,,	,,	20·98	20·98	,,	,,	23·58	23.58

the available nitrogen in the soil mixtures. In the fat-free mustard cake Walton [1928] found that about 60 per cent of its nitrogen nitrified in Pusa and Kalianpur soils in 8 weeks' incubation, which substantially agrees with the results obtained in the nitrification of apricot seed cake and points to its suitability as a nitrogenous manure like mustard cake. In the controls, the amount of soil nitrogen nitrified in Solon soil is the least, being about 4 mg. only, and in Kalianpur and Solon soils the amounts nitrified are about 9 and 14 mg. respectively.

A closer examination of the data reveals some interesting points with regard to the manner in which the nitrogen changes takes place in these soils.

PUSA SOIL

Nitrogen changes of the cake in Pusa soil are shown in Fig. 1.

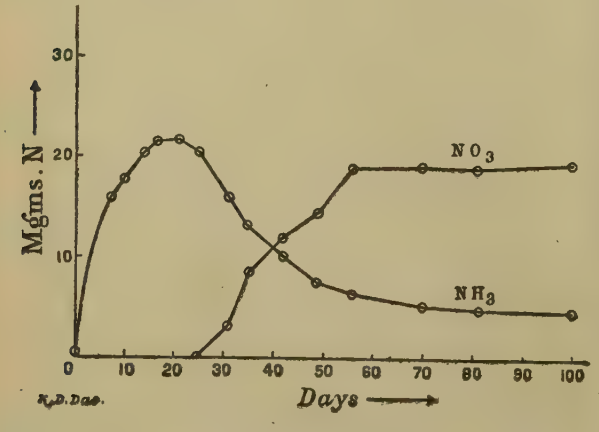

FIG. 1. Nitrogen changes of apricot seed cake in Pusa soil

There is an abundant formation of ammonia from the cake in Pusa soil from the very start, which sharply increases and reaches the maximum in the first three weeks' incubation. Then it rapidly falls off during the next five weeks, after which it slackens and then remains practically constant till the 14th week's incubation, when the evolution of about 5 mg. of nitrogen as ammonia still persists. The immediate effect of the production of hydrocyanic acid as a result of hydrolysis of the cake and of ammonia in the cake-treated soil appears to have completely retarded the formation of nitrate for the first $3\frac{1}{2}$ weeks and also of nitrite for about two weeks. The negative values in Table II point to the fact that in the cake-treated soil there is a lesser production of nitrite and nitrate than in the control (soil alone) for the periods of time noted therein due perhaps to the toxic effect of hydrocyanic acid produced on the nitrifying flora of the soil. After $3\frac{1}{2}$ weeks the nitrate formation rapidly pushes forward reaching the maximum in 8 weeks accompanied by a gradual fall of ammonia, and then remains practically constant till the 14th week's incubation. After the second week the amount of nitrite formed rapidly increases and reaches the maximum in $4\frac{1}{2}$ week's incubation. Then it slopes down quickly to a negligible quantity after the 5th week.

KALIANPUR SOIL

Nitrogen changes of the cake in Kalianpur soil are shown in Fig. 2.

In the cake-treated Kalianpur soil the accumulation of ammonia is considerably less in the initial stages of incubation than in the cake-

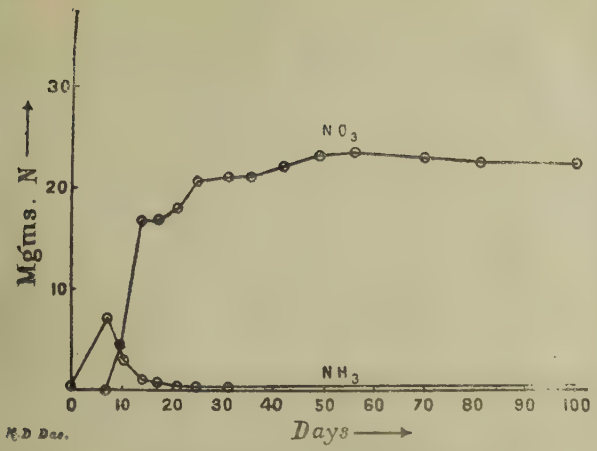

FIG. 2. Nitrogen changes of apricot seed cake in Kalianpur soil

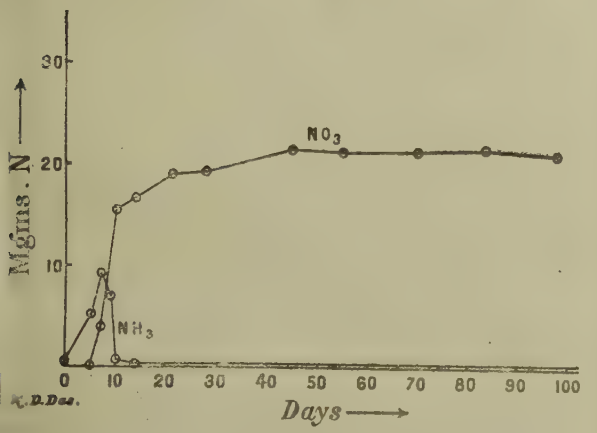

FIG. 3. Nitrogen changes of apricot seed cake in Solon soil

treated Pusa soil. Its retarding effect, if any, coupled with the production of hydrocyanic acid as a result of hydrolysis of the cake, on the formation of nitrate is pronounced in the 1st week's incubation. In the next week there is a sharp fall in the accumulation of ammonia and the curve of its formation solpes down, remaining practically constant after the 3rd week. The nitrate formation curve, on the other hand, initially lagging behind the control during the 1st week as shown by the negative values of nitrate in Table II for that period, shoots up steeply for the next 2½ weeks. Then it slackens reaching the maximum in the 7th week and later on remains practically constant till the 14th week's incubation.

SOLON SOIL

Nitrogen changes of the cake in Solon soil are shown in Fig. 3.

In the cake-treated Solon soil the cake simulates its behaviour in Kalianpur soil. Here an experiment with a fat-free sample of the cake was included in order to determine its superior action, if any, to the untreated cake during the course of nitrogen transformation. The original cake contained as much as 10 per cent of oil, which is believed to retard the action of soil organisms on it. Although the amount of nitrogen converted into available forms is only 4 per cent higher in the fat-free sample than in the original cake, the course of action is similar in both the cases and follows the same relationship between ammonia and nitrate formation as in the case of Kalianpur soil.

A critical examination of the nitrogen changes reveals an initial production of hydrocyanic acid from the cake, the immediate depressing effect of which is apparent on the formation of both nitrite and nitrate in all the three soils experimented with. This effect however dissipates in about a week's time in Kalianpur and Solon soils, and in 3½ weeks in the calcareous Pusa soil.

There is some controversy on the depressing effect of ammonia on nitrifying organisms. Boulanger and Massol [1905] found that the growth and activity of nitrate bacteria is not injured by the ammonium salt, but by free ammonia. Omeliansky [1900] and Meyerhoff [1917] observed that a high concentration of ammonia or nitrite is harmful to the progress of bacterial nitrification. On the other hand, later workers, such as, Fred and Davenport [1921], and Joshi [1928] found that nitrifying organisms can tolerate much larger amounts of organic matter and ammonical nitrogen than those given by the early investigators. Hydrocyanic acid thus appears to be mainly responsible in exercising a toxic effect on the normal activities of nitrite and nitrate bacteria in the soil in the initial stages of incubation, but, later on, this injurious effect is minimized and ultimately disappears owing to the dissipation of hydrocyanic acid. Then the conversion of ammonia into nitrate follows by the gradual preponderance of nitrifying organisms.

II. EFFICIENCY OF APRICOT SEED CAKE AS NITROGENOUS MANURE

It has already been demonstrated above that 54 to 63 per cent of the nitrogen present in the cake is transformed into available forms in three different types of soil as shown in Tables II and III in about two months. It therefore became of interest to determine how far this available nitrogen derived from the cake could be utilized for growing crops in these soils, and, as a consequence, if this cake could find an application as a suitable nitrogenous manure for soils, especially in the neighbourhood of its production.

In order to test this, a series of pot experiments was started in the winter of 1932 with the calcarous Pusa soil. Wheat was chosen as the *rabi* (winter) crop which responds readily to nitrogenous manures. Four pots of similar dimensions, e.g. 9 in. in diameter by 12 in. high formed a group and received similar treatment. The pots contained 15 kilos of air-dry soil in each and 16 per cent of moisture was maintained in the soil throughout the experiment. The apricot seed cake was applied to the pots according to the following scheme, given in Table IV.

TABLE IV

Scheme of application of apricot seed cake to pot-culture experiments

Pot numbers	Mg. nitrogen per kilo of soil	Lb. manurial constituents per acre from the cake		
		N	P_2O_5	K_2O
1 to 4	Control	..	..	..
5 to 8	10	20	4·47	3·27
9 to 12	20	40	8·94	6·54
13 to 16	40	80	17·88	13·08
17 to 20	50	100	22·35	16·35

Pusa Wheat No. 12 was sown on 10 November 1932 and the crop harvested on 20 March 1933. In order to determine how far the residual effect of the manure persisted in Pusa soil, a second crop of *ragi* (*Eleusine coracana*) was raised in the following summer in these very pots without any further manurial treatment. *Ragi* seeds were sown on 11 June 1933 and the crop was harvested on 3 October 1933.

Although the weights of both grain and straw per pot were recorded separately, only the mean yields of grain per treatment for both wheat and *ragi* are given in Table V along with the standard errors calculated by Fisher's [1932] analysis of variance. As a matter of fact, similar conclusions emerge from the examination of data either for grain or straw.

In order to obtain further confirmatory data, pot experiments were instituted in the winter of 1933 with Solon and Kalianpur soils. Similar pots were used and the same treatments followed as in Pusa soil. Pusa Wheat No. 12 was sown on 3 November 1933 and the crop raised harvested on 14 March 1934. The mean yields of grain per treatment both for Solon and Kalianpur soils are given in Table VI along with the standard errors calculated by Fisher's [1932] analysis of variance.

TABLE V

Effect of apricot seed cake as a nitrogenous manure in Pusa soil in 1932-33

Mg. N per kilo of soil	Primary effect		Residual effect	
	Wheat 1932-33		*Ragi* 1933	
	Mean yield in gm.	Per cent increase over control	Mean yield in gm.	Per cent increase over control
Control	4·34	..	9·08	..
10	8·01	84·6	10·63	17·1
20	8·26	90·4	10·13	11·6
40	10·08	132·3	10·55	16·2
50	11·06	155·0	12·20	34·4
Standard error for comparison of mean yields		0·59		0·98
Critical difference for $P=1$ per cent		1·74		2·89
for $P=5$ per cent		1·26		2·09

TABLE VI

Efficiency of apricot seed cake as a nitrogenous manure on the yield of wheat in Solon and Kalianpur soils in 1933-34

Mg. N per kilo of soil	Solon soil		Kalianpur soil	
	Mean yield in gm.	Per cent increase over control	Mean yield in gm.	Per cent increase over control
Control	12·43	..	6·08	..
10	14·83	19·3	11·80	94·1
20	15·88	27·8	17·03	180·1
40	21·80	75·4	19·63	222·8
50	24·08	93·7	24·18	300·0
Standard error for comparison of mean yields		1·49		1·79
Critical difference for $P=1$ per cent		4·39		5·28
for $P=5$ per cent		3·18		3·82

From a consideration of the cropping results of the three soils, it is evident that the increase in crop yield over the control is high with every treatment of the cake. In the case of Pusa soil two

ops were raised after a single application of the ke, viz. (1) wheat in the winter of 1932 followed (2) *ragi* in the following summer of 1933, the tter crop showing the residual effect of the anure. Cropping results showed that the crease in the yield of wheat over the control as considerable according to the increasing oses of the manure applied and that the differnces in mean yields of grain between control nd every other treatment were significant being reater than the critical-value of difference even r one per cent level of significance. The aximum crop was obtained by the application f 40 mg. of nitrogen per kilo of soil as apricot ed cake, although a little better crop was prouced by 50 mg. of nitrogen per kilo which was ot however statistically significant.

In the case of *ragi* crop, although the increase n the yield of grain over the control indicated he residual effect of every treatment of the cake, he residual effect of 50 mg. of nitrogen only ave significantly higher yield than the control.

It may therefore be concluded that the residual ffect of the cake can persist till the next succeeding crop in calcareous soils, only when it is nitially applied at the rate of 50 mg. of nitrogen er kilo of soil.

In the case of Solon and Kalianpur soils the ncrease in the yield of wheat over the control as high with the increasing doses of nitrogen pplied in the form of apricot cake. The differnces in mean yields of grain between control nd every other treatment of the cake were iso highly significant as in the case of Pusa oil except for 10 mg. of nitrogen in Solon soil howing no significant increase. It will be urther noticed that the application of 40 and 50 g. of nitrogen per kilo of soil gives the maximum ield of wheat in Solon and Kalianpur soils respectively.

A closer examination of the cropping results of the three soils reveals the fact that the maximum crop response was attained to the application of apricot seed cake in Kalianpur soil, next came in order the Pusa soil, and last of all was he Solon soil. It may therefore be concluded hat apricot seed cake can serve as a suitable nitrogenous manure perhaps for various types of soil, and especially in agricultural lands in the neighbourhood of Solon where it is available n plenty, but at present wasted as a fuel only.

Summary and general conclusions

1. About 60 per cent of nitrogen present in the apricot seed cake may be transformed into available forms in Kalianpur, Pusa, and Solon soils on 7 to 8 weeks' incubation.

2. Of the soil nitrogen present, the least amount is nitrified in Solon soil which nevertheless contains three times as much organic nitrogen as in the other soils; the highest nitrification takes place in Pusa soil, and Kalianpur soil stands midway in this respect, the soil nitrogen nitrified being 4, 14, and 9 mg. respectively. The same order of the nitrification of the cake too is maintained in these soils.

3. In all the three soils a large evolution of ammonia takes place initially from the cake. Later on, however, it gradually goes down to a small quantity.

4. An appreciable quality of hydrocyanic acid is found in the cake, indicating the presence of some cyanogenetic compound in it. Its content is high enough to prove fatal to the cattle, if the cake is fed to them.

5. Hydrocyanic acid is a product of hydrolysis of the cake in the soil. It might have contributed towards retarding the formation of both nitrite and nitrate in the early stages of incubation. This injurious effect is however later on reduced to a minimum and ultimately nonexistent.

6. Pot experiments showed that the application of 40 mg. of nitrogen as cake per kilo of soil produced the maximum yield of wheat in Pusa and Solon soils, and 50 mg. in the case of Kalianpur soil. The results were found to be statistically significant.

7. In Pusa soil the increased yield of wheat over the control was high according to the increasing doses of the cake varying from 10 to 50 mg. of nitrogen per kilo of soil. The residual effect of 50 mg. of nitrogen applied initially per kilo of soil gave significantly high yield of *ragi* (*Eleusine coracana*) over the control, the rest of the treatments giving somewhat higher yields than the control, though not statistically significant. The residual effect of the cake was not however tested in Solon and Kalianpur soils.

8. In Kalianpur soil the increased yields of wheat over the control were remarkably high with varying doses of the cake.

9. In Solon soil the yields were the least, compared to Pusa and Kalianpur soils. The results were however statistically significant except for 10 mg. of nitrogen per kilo of soil.

10. The cake being thus effective as a nitrogenous manure with an important crop like wheat in three dissimilar types of soil, it will undoubtedly prove as an efficient nitrogenous manure for soil which are particularly deficient in this constituent, and especially so in agricultural lands in the neighbourhood of Solon where it is available in plenty, but at present wasted as a fuel only.

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STUDIES ON THE ROOT-ROT DISEASE OF COTTON IN THE PUNJAB

XIV. EFFECT OF SOIL TREATMENT ON DISEASE INCIDENCE

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(With one text-figure)

Root-rot of cotton is the most destructive disease of this crop in the canal irrigated colonies of the Punjab. The soils in these areas are predominantly light loam in texture with 15-20 per cent clay, and are mostly alkaline in reaction. The degree of alkalinity varies considerably and may even go up to *p*H 9 or so in some highly alkaline soils. The causal organisms *Rhizoctonia Solani* Kühn and *Macrophomina phaseoli* (Maubl.) Ashby [*Rhizoctonia bataticola* (Taub.) Butler] are soil-inhabiting fungi and bring about the death of the plants by attacking their roots. It was considered possible therefore to control the disease by alteration of soil conditions as affecting the host and the organisms. The experiments reported in this paper were conducted with this end in view during 1935-1940. Such methods of control are directed to the eradication of the fungus from the soil during its resting period, and the control of the disease may be effected by checking the activity of the fungus during its parasitic phase, by increasing resistance of the host, and by creating adverse soil conditions for the sub-soil development and parasitism of the organism concerned.

Such methods have proved successful in the control of several plant diseases. The most familiar example is that of the control of potato scab by application to the soil of chemicals or fertilizers with a view to increasing soil acidity. The severity of root rot of wheat seems to be influenced by the time and mode of tillage [Sewell and Melchers, 1924], and the use of fertilizers has been shown to result in the control of root-rot of peas [Haenseler, 1930]. Neal [1928], Miles [1929, 1930] and Young and his associates [1932] have suggested control of *Fusarium* wilt of cotton by addition of potassium salts to the soil.

Experimental

All the experiments reported herein were conducted at Lyallpur on land which was heavily and uniformly infected with the disease in order to get reliable and comparable data. The distribution of infection in a large number of fields had been mapped out during the previous seasons. Fig. 1 shows the method of mapping. Black lines in the figure indicate the positions of plants killed by root-rot. Cotton was sown in the month of May which is the most favourable period for development of the disease. Both *Desi* (*Gossypium indicum*) and American (*G. hirsutum*) cottons were used in these experiments, and sowings were done in lines 2½ and 3 ft. apart respectively.

A. *Effect of soil fumigation*

In 1937 an infected field was divided into 18 plots each 12 ft. × 12 ft., and holes 1 ft. deep were bored with a soil sampler at a distance of 2 ft. from one another. Altogether 36 holes were bored in each plot. Paradichlorobenzene or calcium cyanide was added in the holes at the rate of 340 lb. per acre about two months before planting cotton. In the control plots the holes were bored and filled up with soil without the addition of any chemical. Six plots were treated with each of the chemicals and six were kept as controls. The experiment was laid out on a randomized block system. *Desi* cotton variety *Mollisoni* 15 was sown on 15 May 1937, and observations on the incidence of the disease were made at weekly intervals throughout the growing season. The data are summarized in Table I.

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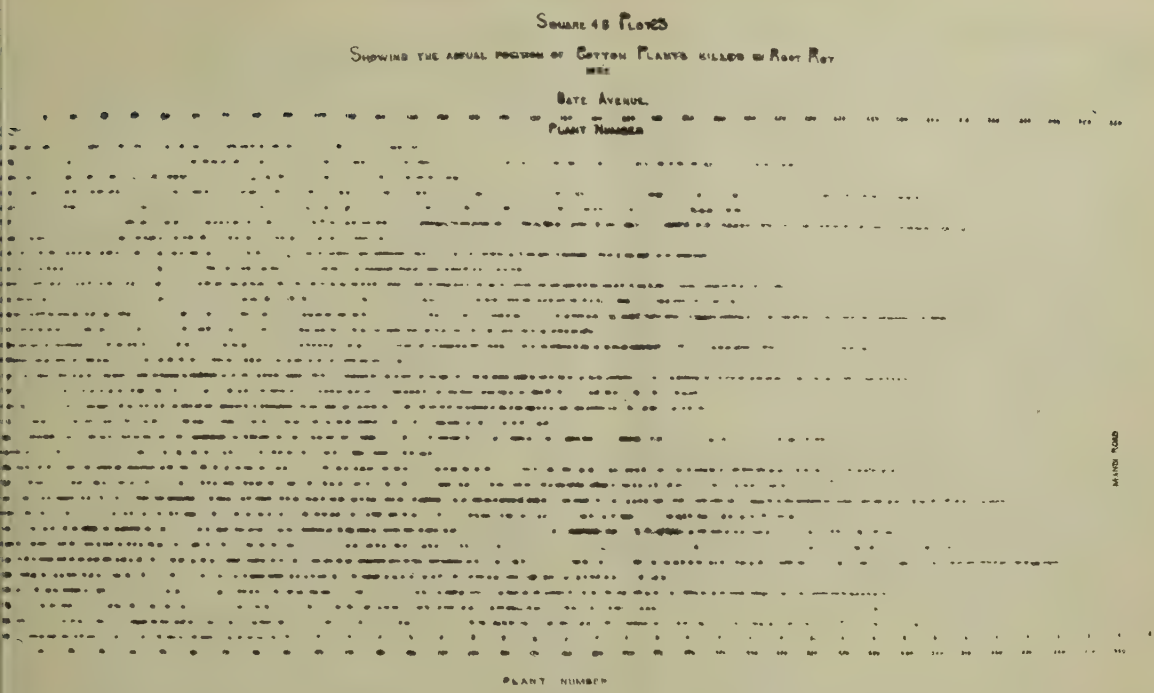

Fig 1

Table I

Effect of soil fumigation

Treatment	Total No. of plants	Total plants killed	Average per cent mortality	Average yield of seed cotton per acre
				lb. oz.
ium cyanide	218	67	28·32	425 2
dichlorobenzene	191	10	4·67	374 15
trol	226	69	29·53	621 2

t was observed that the disease incidence in plots treated with paradichlorobenzene was preciably reduced, but germination in all these ts was considerably delayed and the plants nained comparatively much smaller and stunt-

It is therefore difficult to explain as to whe- r low incidence of the disease in the plots ated with paradichlorobenzene was due to this atment or to late germination which amounts late plantings in the month of June. It has eady been shown [Vasudeva, 1937; 1943] t the disease can be controlled by planting tons late towards the end of June. Yield of d cotton in the treated plots was lower than that tained from the controls.

In laboratory tests made with calcium cyanide asudeva, 1937] it was observed that hydro- anic acid gas penetrates up to a depth of 18 after six days and kills the resting bodies the fungi concerned. It appears from the results recorded in Table I that this chemical, when tested under field conditions, almost failed to check infection, and this failure was probably due to the inability of the disinfectant to reach the root rot organisms in the deeper layers of the soil. Fumigation of the soil by means of chemicals appears to be unsatisfactory because of the cost involved and the possibility of the disinfectants proving inaffective when applied under field conditions.

B. *Effect of cultural treatment*

Experiments in connection with the modes of perennation of the fungi causing root-rot showed that the diseased roots of cotton found in affected patches in the field invariably yielded the causal fungi in culture. These organisms were also isolated from roots of cotton plants collected from fields allowed to fallow after removal of the crop, and the resting bodies of the fungi obtained from such roots collected from various localities were

found to be viable when cultured on an artificial medium.

In the summer of 1935 roots of cotton plants bearing the resting bodies of the fungi were left in the open exposed to atmospheric conditions and were also buried in the soil at various depths ranging from one to five feet. These bodies were found to be viable even after three years and isolations from the roots yielded *Macrophomina phaseoli* in all cases, but *R. Solani* was very rarely recovered. The fungi are also capable of over-wintering under frosty conditions. In view of this normal cultural treatments were so varied so as to minimize the source of infection in the soil.

(*a*) *Effect of removal of diseased debris, addition of farmyard manure and flooding.*—An experiment involving these treatments singly and in combination with a non-treated variant, i.e., eight variants in all was laid out in 1939-40 on a randomized block system. Five repeats of each treatment were kept.

A heavily infected field was divided into 40 plots, each plot being 24 ft. × 14 ft. Removal of diseased debris was as far as possible effected with the help of plant pullers and then by deep ploughing with a furrow-turning plough and picking up the roots by hand. Altogether, flooding of the plots was done five times before planting cotton. The time required for flooding each line of four plots, during the first three irrigations was 7 to 8 min., and in the last two irrigations only 6 to 7 min. were taken in flooding each line. The time required for giving a normal irrigation, i.e. 2½ in. water after sowing cotton was about 4 to 5 min. Well rotted farmyard manure at the rate of 18 tons per acre was added. All precautions were taken to obtain reliable and comparable data.

On 20 May 1939, *Desi* cotton variety *Mollisoni* 39 was sown in all the 40 plots. Observations for disease incidence were taken for the first time on 19 June 1939 and thereafter at weekly intervals. The average per cent mortality due to root-rot in various treatments is summarized in Table II

TABLE II

Effect of different treatments on disease incidence

Treatment	Untreated—not flooded			Treated—flooded		
	Total No. of plants	Total killed due to root-rot	Average per cent mortality	Total No. of plants	Total killed due to root-rot	Average per cent mortality
1. Addition of farmyard manure	739	495	69·1	747	390	52·0
2. Removal of diseased debris	750	494	65·9	748	183	24·4
3. Removal of diseased debris and addition of farmyard manure	746	245	32·9	747	404	54·0
4. Untreated control	736	296	40·1	748	439	58·6

Indications of reduction in mortality were obtained only in the plots from which cotton roots had been removed and the plots had been flooded. The results, however, were barely significant.

A similar experiment was laid out in 1940-41 and three repeats of each treatment were kept. No indication of any appreciable reduction in mortality in any of the treatments was obtained.

The effect of flooding alone was also studied in an experiment where cotton variety *Mollisoni* 15 was sown in the middle of May on ridges as well as on flat. In controls only normal irrigation was given. No appreciable difference in mortality in the treated and untreated plots was observed.

The effect of removal of old roots on the development of the disease was studied in another experiment in which soil was dug up to a depth of 2½ ft. and from it all pieces of cotton roots were carefully removed. The disease incidence in the plots so treated was 40·7 per cent as compared to 80 per cent in the untreated control.

(*b*) *Effect of trenching.* The experiment was conducted in plots, 30 ft. × 17 ft. each. About six weeks before sowing cotton the soil in two plots was dug up to a depth of 6 ft. and in another two plots digging was done only to a depth of 4 ft. After a couple of days the earth was turned over and replaced in the pits so dug. All the plots were then irrigated. No digging was done in the control plots. American cotton variety 4F was sown on 23 May 1938, and observations on the incidence of the disease were made weekly. The data are set out in Table III.

TABLE III
Effect of trenching on disease incidence

Treatment	Total plants	Total killed	Average per cent mortality	Average out turn of seed cotton per acre	
				lb.	oz.
1. Trenched 6 ft.	386	35	9·0	1262	12
2. Trenched 4 ft.	325	142	42·4	706	5
3. Untrenched check	358	176	48·1	624	3

The data clearly show that the incidence of root-rot was greatly reduced by trenching up to a depth of 6 ft. and that the outturn of seed cotton in the trenched plots was considerably increased. The general growth of plants in the trenched plots was very vigorous. This experiment was repeated for two consecutive years with similar results but, as this method of control is very laborious, it is not likely to be adopted in practice.

(*c*) *Effect of tillage.*—An experiment to test the effect of tillage on the incidence of root-rot disease was laid out at the British Cotton Growers Association's Farm at Khanewal. Three isolated fields, each 190 ft. × 110 ft.. in which cotton plants had died of root-rot in the previous seasons, were selected. Each field was divided into five plots, and each plot was 110 ft. × 38 ft. Five treatments, i.e., continuous cropping with cotton, summer tillage, winter tillage, 12 months tillage, and 24 months tillage were replicated three times. Before sowing all fields were cultivated by a furrow-turning plough at weekly intervals throughout the period of the experiment. Every effort was made to plough to a depth of 6 in and to remove all weeds. Occasionally rain hampered these operations, but the average of one ploughing per week was always made up.

In the plots where cotton was continuously cropped, only normal cultivation was given, and the test crop of *Desi* cotton var. *Mollisoni* 15 was planted in May 1935, 1936 and 1937, according to local cultural practices. The soil in the summer and winter tillage plots was ploughed weekly during April to September, 1935, and October to February, 1935, respectively. The cultivation in the 12 months tillage plots was carried out from April 1935 to April 1936. Test crop in all such treated plots was sown in May 1936. In the 24 months tillage plots weekly cultivation was given from April 1935 to May 1937 before cotton crop was sown.

The extent of root-rot infection in a particular plot was determined by the number of plants killed by the disease. No regular differences in disease incidence n the treated plots and those continuously cropped with cotton crop were observed. In the 12 months tillage treatment only two plots out of three in 1936 showed some reduction in mortality, whereas the mortality in the third plot was slightly higher than the check plots. In the 24 months tillage treatment also the fall in the incidence of the disease was observed only in two plots. The figures on mortality recorded in 1937 in the treated plots as compared to those in plots continuously cropped with cotton are given below.

Continuous cropping	24 months tillage
54·16	14·07
44·06	47·30
19·16	17·26

C. *Effect of fertilizers.* Experiments to control the disease by direct application of fertilizers to the soil were carried out from 1935 to 1940, and are described, below:

(*a*) *Organic manure.*—The beneficial effect of organic manure applied in deep furrows on the incidence of *Phymatotrichum* root-rot of cotton in Arizona in the U.S.A.. has been demonstrated by King and his associates [1926, 1929, 1934]. Similar trials were conducted at Lyallpur in 1935 and 1937. In 1937 forty-eight trenches, each 50-ft. long, 1½ ft. deep and 1-ft. wide, were dug in a uniformly infected area. These were grouped into eight lots of six trenches each. In each group three trenches were manured about one month prior to sowing cotton, at the rate of 14 tons per acre. In 1935 only 32 trenches were dug and divided into eight lots of four each. Out of these four only two were manured at the rate of 30 tons per acre. The unmanured trenches in each group were refilled with the soil and served as checks. In 1937 *American* cotton variety 4F and in 1935 *Desi* cotton variety *Mollisoni* 15 were sown in the centre of each trench in the middle of May. Observations on mortality due to root-rot disease were made at weekly intervals throughout the cotton season. No regular differences in the incidence of root-rot in the manured and unmanured furrows were observed. The cumulative effect of this treatment on disease incidence was not studied. The data collected in 1937 are given in Table IV.

TABLE IV

Effect of addition of farmyard manure in deep furrows

Group	Average per cent disease incidence	
	Manured	Unmanured
I	0·57	2·48
II	0·59	9·15
III	31·20	73·85
IV	90·22	81·32
V	85·84	87·33
VI	89·75	88·82
VII	84·26	78·18
VIII	93·86	90·05

(*b*) *Artificial fertilizers.* The effect of a number of fertilizers on disease incidence was tested in uniformly infected fields. *Desi* cotton variety *Mollisoni* 15 was sown during the most favourable period for development of the disease. The data of three of some typical experiments are summarized in Table V, VI and VII. Calcium was applied in three different forms, viz. gypsum, lime-stone or lime, and calcium chloride. The soil at Lyallpur where these experiments were conducted tends to be alkaline, although it gives good yields. In some of the trials gypsum and other calcium compounds were also included, so that the alkalinity of the soil may not interfere with these experiments. These were applied in high doses because some of the work on the reclamation of alkaline soils (by changing sodium clays into calcium clays) which was conducted at the time had shown that in certain localities only high amounts of gypsum and lime, owing to the comparatively low solubility of calcium, have been found to give good results.

In the third experiment (Table VII) the effect of potassium was studied alone and in the presence of calcium for obtaining a clearer comprehension of the results ; calcium chloride was used alone as well. These two chemicals were used in the form of chlorides so that there may be no differences in the acid radical and differences in the results, if any, may be directly ascribed to the two types of basic ions.

TABLE V

Effect of fertilizers on disease incidence

No.	Treatment	Rate per acre	Total plants (3 plots)	Plants killed by root-rot	Average per cent mortality (3 plots)
1	Ammonium sulphate	85 lb. N.	297	75	25·2
2	Superphosphate	100 lb. P_2O_5	296	94	31·7
3	Ammonium sulphate + superphosphate	85 lb. N + 100 lb. P_2O_5	294	82	27·9
4	Silt collected from canal beds	73 tons	298	69	23·1
5	Untreated control		299	92	30·8

TABLE VI

Effect of fertilizers on disease incidence

No.	Treatment	Rate per acre	Average per cent mortality	
			1935-36 (4 plots)	1936-37 (4 plots)
1	Lime stone	4480 lb. CaO	49·5	77·1
2	Farmyard manure	200 lb. N.	55·3	67·1
3	Lime stone + F.Y. manure	4480 lb. CaO + 200 lb. N.	36·7	70·6
4	Lime stone + superphosphate	4480 lb. CaO + 100 lb. P_2O_5	48·6	67·8
5	F.Y. manure + ammonium sulphate + superphosphate	200 lb. N. + 85 lb. N + 100 lb. P_2O_5	26·2	50·6
6	Untreated control		32·3	53·8

TABLE VII

Effect of fertilizers on disease incidence

No.	Treatment	Rate per acre	Average per cent mortality (6 plots)	Average yield per acre	Yield per 100 plants
				Lb. oz.	Lb. oz.
1	Calcium chloride . . .	2281 lb. CaO	35·9	894 3	9 1
2	Potassium chloride . . .	210 lb. K.	31·4	1309 2	10 11
3	Calcium chloride + potassium chloride	2281 lb. CaO + 210 lb. K.	34·8	1147 10	10 6
4	Untreated control . . .	..	59·6	712 15	9 7

No appreicable reduction in the incidence of ot-rot was observed in the plots treated with rious chemicals except in the case of plots where lcium chloride and potassium chloride alone d in combination with each other had been plied. The disease incidence in these plots s lower than in the untreated control plots. ere were also indications of increased yield ere potassium chloride had been applied.

In another experiment in which a still heavier se of potassium chloride was applied there was change in the development of root-rot, but the ld of seed cotton per 100 plants was 21 lb. oz. as compared to 15 lb. 12 oz. in the untreated ntrols.

Varying quantities of gypsum, i.e. from 2 to 6 tons (1456 lb. to 4368 lb. CaO) per acre were also tried in 1938-39. The plots treated with 6 tons of gypsum showed an average per cent root-rot mortality of 57·8 as against 59·5 in the check plots. Lime was applied at the rate of 3 tons (5100 lb. CaO) per acre, but both the disease incidence and yield of seed cotton were unaffected.

In 1937-38 the effect of certain minor elements was studied in a heavily infected field which was divided into sub-plots, 18 ft. × 12 ft. each. Each treatment was replicated five times. *Desi* cotton variety *Mollisoni* 15 was planted on 20 May 1937. Observations on disease incidence were made weekly. Data showing the effect of different treatments on disease incidence and out turn of seed cotton are summarized in Table VIII.

TABLE VIII

Effect of minor elements on disease incidence

No.	Treatment	Rate per acre	Total plants	Plants killed	Average per cent root rot mortality	Average yield of cotton seed	
						Per acre	Per 100 plants
						Lb. oz.	Lb. oz.
1	Borax (anhydrous) . .	2·15 lb. B.	267	138	31·40	827 12	16 4
2	Zinc sulphate . .	2·27 lb. Zn.	265	155	46·18	607 13	15 5
3	Manganous chloride . .	6·94 lb. Mn.	284	135	34·71	840 11	14 0
4	Untreated control . .	..	287	135	39·40	944 2	15 12

The elements tested singly failed to exercise any ourable influence on the incidence of the disease d on yield.

In another experiment small plots each 11 ft. × ft., were treated with aluminium sulphate and rous sulphate at the rate of 500 lb per acre 9·12 lb. Al_2O_3 and 262·37 lb. Fe_2O_3). Iron d aluminium were not deficient in the soils under se experiments but they were included to study ir effect on the incidence of the disease. The ts were randomized and 6 repeats of each treatnt were kept. Untreated plots served as check. e observations on disease incidence were made roughout the cotton season. Treated and control plots did not show any difference in disease incidence but average yield of seed cotton per acre in the treated plots was lower (626 lb.) as compared to the check plots (747 lb.).

Experiments described above conducted with a view to control the root-rot disease of cotton show that soil fumigation, various cultural treatments and application of fertilizers are of no help in controlling the disease. As already reported [Vasudeva, 1939], even change in soil-reaction failed to reduce the disease incidence. However two simple and most effective methods for the control of the disease in the Punjab, i.e., varying of sowing date and mixed cropping, have already

been described in the preceding numbers of this series [Vasudeva, 1943 ; 1941].

SUMMARY

Results of experiments on soil fumigation, various cultural treatments described in this paper and the application of fertilizers to the soil have not given any indication of the possibility of evolving a practical method of control of root-rot disease of cotton in the Punjab.

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THE COMBINED ACTION OF ORGANIC MATTER AND PHOSPHATIC FERTILIZERS IN SOILS

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NOTWITHSTANDING the wide variation of soils in different parts of the world, the beneficial action of phosphatic fertilizers when applied in intimate contact with green or other organic manures has been universally recognized. Those who strongly advocate the use of either natural or artificial phosphatic fertilizers for soil amendment always advise that they should be applied in conjunction with decaying organic matter. The explanation usually given for this practice is that organic acids, carbon dioxide, and nitrous acid resulting from the decomposition of organic matter are active agents in making the phosphates available to plants. Strangely, however, attempts made in the laboratory to test this explanation have not given positive results.

It is, however, conceivable that organic phosphates may be produced by the chemical action or through absorption of phosphates with humic or organic acids resulting from the decaying organic matter in the soil. And it is quite probable that such organic phosphates are significantly related to the crop yield resulting from the combined application of phosphatic fertilizers and organic matter.

The possibility of this effect has not hitherto been sufficiently recognized, and it is to throw light on this aspect of the problem that the present investigation was undertaken.

Recent experience does not justify the assumption that the state of solution is necessary to availability of plant food. As for instance, direct experiments by Truog [1914] and Marais [1922] have shown that the insoluble iron and aluminium phosphates which are believed to be hardly available as plant food, are very well utilized by plants as sources of phosphorus. Therefore, the inevitable conclusion is that solubility is not the dominating factor of availability.

Further, highly dispersed material, though not present in a true solution, can diffuse into plant cells. As for instance, Czapek [1905] states that colloids can enter plant cells, and Pfeffer [1900] records the diffusion of silicic acid into the cell sap of plants. Jennings [1918] has shown that colloidal silica gel can be absorbed by wheat seedlings in water culture solutions.

In the light of the above observations Comber [1922] developed a hypothesis as to the availability of mineral plant food in soils. According

him, food materials in the colloidal state are ily taken up by plants and the cell sap of the t hair possibly derives its food material without acid secretion as formerly supposed. As for mple, ferric phosphate loses its colloidal pro- ties on ignition, as a result of which it becomes vailable to the plant according to Prianis- nikow [1905]. On the other hand, aluminium sphate retains its colloidal properties after ition and remains available for the plant. us, the colloidal condition of phosphates is in a ge measure related to their solubility and their ilability to the plant.

Now if it can be demonstrated that organic sphates resulting from the action of fermenting anic matter on phosphatic fertilizers possess oidal properties, remain in the soil in a more ersed state than the inorganic phosphates d as fertilizers, and eventually become more ilable to plants, then the increased crop yield obtained from phosphates when applied to soils in conjunction with organic matter may be explained to have originated from the colloidal organic phosphates formed.

In order to test this, composting experiments were instituted with lucerne as a typical source of organic matter. Monocalcium phosphate, the chief phosphatic constituent of superphosphate, and dicalcium phosphate were used in the following proportions for making composts with lucerne :

(1) 70 lb. of lucerne alone
(2) 60 lb. of lucerne + 237.32 gm. of monocalcium phosphate (= ¼ lb. P_2O_5)
(3) 60 lb. of lucerne + 257.50 gm. of dicalcium phosphate (= ¼ lb. P_2O_5).

It took about four weeks to complete the decomposition of lucerne. When the whole mass was homogeneous, the stuff was dried in the sun and sampled. The chemical composition of the composts is given in Table I.

TABLE I

Chemical composition of composts

o.	Kind of composts	N per cent	By HCl		Per cent soluble P_2O_5 by	
			Total P_2O_5 per cent	Total K_2O per cent	1 per cent citric acid	1 per cent K_2CO_3
1	Lucerne alone	2·712	1·509	7·898	1·032	0·355
2	Lucerne + monocalcium phosphate .	2·717	4·861	7·805	1·952	0·831
3	Lucerne + dicalcium phosphate . .	2·576	4·279	6·683	2·076	1·157

TABLE II

Balance sheet of P_2O_5 in composts

o.	Kind of composts	Lb. P_2O_5 in compost			Lb. P_2O_5 extracted by		
		HCl Sol. P_2O_5 in lucerne	Added P_2O_5	Total P_2O_5	HCl	1 percent citric acid	1 percent K_2CO_3
1	Lucerne alone	0·0815	nil	0·0815	0·0815	0·0557	0·0193
2	Lucerne + monocalcium phosphate .	0·0739	0·2500	0·3239	0·2625	0·1054	0·0449
3	Lucerne + dicalcium phosphate . .	0·0739	0·2500	0·3239	0·2311	0·1121	0·0625

	Per cent of HCl soluble P_2O_5 extracted by		Per cent of total P_2O_5 extracted by		
	1 per cent citric acid	1 per cent K_2CO_3	HCl	1 per cent citric acid	1 per cent K_2CO_3
1	68·39	23·66	100	68·39	23·66
2	40·16	17·10	81·04	32·54	13·86
3	48·52	27·04	71·34	34·61	19·29

It will be noticed that, although the same amount of P_2O_5 was originally present while making the last two composts, the final products appreciably differ in composition in their relation to P_2O_5 content. This is shown by the different proportions of P_2O_5 extracted with the various solvents, e.g. hydrochloric acid, 1 per cent citric acid of Dyer [1894] and 1 per cent potassium carbonate solution of Das [1930]. This effect may be further examined by drawing up the balance sheet of P_2O_5 in the composts as shown in Table II. Each compost had a dry weight of 5·4 lb.

The indefinite composition of the various composts is clearly reflected in the different solubilities of their P_2O_5 content in the solvents tried. The phosphate composts may still, however, contain some of the added inorganic phosphates unacted upon by the fermenting organic matter ; this may partly account for the different amounts of P_2O_5 extracted. With a view to eliminate this possibility and in order to obtain more rigorous proof as to the variable nature of the composts, humus was extracted from the individual composts in the following manner and P_2O_5 determined in the same for comparison.

Composts were shaken for six hours in the cold with one per cent potassium carbonate solution or water alone in the ratio of 10 gm. of substance to 100 c.c. of the solvent and allowed to stand overnight. To the deep brown filtrates hydrochloric acid was added in slight excess, which precipitated humus keeping other substances in solution. The humus was filtered and washed free from hydrochloride acid with water and dried at 100°C. The results of P_2O_5 estimations are given in Table III.

TABLE III

P_2O_5 content of humus extracted from composts with water or 1 per cent potassium carbonate solution

Kind of composts	Per cent P_2O_5 in humus extracted by	
	Water	K_2CO_3
1. Lucerne alone . .	0.8542	0.3582
2. Lucerne+monocalcium phosphate	0.8859	0.6229
3. Lucerne + dicalcium phosphate	0.7741	0.4509

It is evident that the P_2O_5 content of humus obtained from the three sources is different, and consequently the proportion in which fermenting organic matter combines with phosphates is not constant. The nature of these compounds will be better intelligible in the light of the following considerations.

It is well known that humus precipitated by acids is different from humus not so precipitated, both of which play an important role in soil phenomena. They are not definite in composition, consisting of several complex compounds, the nature of which depends on the character of the sources from which they are derived. On carefully examining a number of soils in their vegetation relationships it has been shown that there must be several distinct types of humus, which, however, cannot be classified, according to Russell [1921], for lack of sensitive laboratory methods.

Consequently, some of the organic compounds which are normally present in humus, no doubt, combine by means of adsorption or chemical action with phosphates naturally occurring in lucerne or artificially added as fertilizers, and the complex organic phosphates thus formed, which may be either chemical compounds or adsorption complexes or mixture of both, may not therefore have the same composition. A discussion as to the probable constitution of these complex bodies evidently lies beyond the scope of the present investigation. It was, however, considered essential that these organic phosphates should be isolated, qualitatively at least, to study their suitability as plant food in relation to soil fertility.

In order to do this, individual composts were shaken with water for six hours in the proportion of 10 gm. of substance to 100 c.c. of water and allowed to stand overnight. The deep brown filtrates were then dialysed through parchment paper. None of the brown liquid contained within the parchment bag diffused into outside water, which was changed every day till no trace of P_2O_5 nor the presence of any salt could be detected in it. The complex organic phosphates thus isolated in solution behaved like colloids and did not settle down even on long standing. The results of their P_2O_5 determination are set forth in Table IV.

TABLE IV

P_2O_5 content of dialysed solutions of complex organic phosphates of composts

Complex organic phosphates from composts of	Time taken for dialysis	Mg. P_2O_5 per 100 c.c.
1. Lucerne alone . .	20 days	3·1
2. Lucerne+monocalcium phosphate	16 „	10·2
3. Lucerne+dicalcium phosphate .	23 „	4·9

It is evident that these complex organic phosphates from the three sources are different in constitution with respect to their P_2O_5 content.

Next, in order to test how far these colloidal phosphates could be utilized for supplying the

phosphatic needs of plants, Knopp's nutrient solution was prepared having the following composition for water culture experiments:

$Ca(NO_3)_2$	4 gm.
$MgSO_4, 7\ H_2O$.....	1 gm.
$FeCl_3$	Trace
KNO_3	1 gm.
K_2HPO_4	1 gm. (=0.4081 gm. P_2O_5)
KCl	0·5 gm.

All the potassium salts and the rest are dissolved separately ; the two solutions are then mixed together, diluted, and the volume made up to seven litres with water. The strength of the final solution is 0·011 per cent of salts. On allowing to stand, a little tricalcium phosphate is precipitated which lessens the proportion of calcium and phosphoric acid in the solution. The P_2O_5 was found reduced to 0·043 gm. per litre against 0·0583 gm. in the original solution.

As a preliminary study, a series of water culture experiments was instituted with seedlings of *ragi* (*Eleusine coracana*) in order to test the efficiency of the colloidal organic phosphates against K_2HPO_4 in the Knopp's nutrient solution. The seedlings of about the same size and weight were placed in all the solutions. Loss of water was made up by the addition of water every day. The following solutions were used:

(1) 1200 c.c. of Knopp's nutrient solution ; this served as the *control*

(2) Equivalent Knopp's solution devoid of P_2O_5 *plus* equivalent P_2O_5 (as present in Knopp's solution) in the form of colloidal organic phosphates from the compost of lucerne and monocalcium phosphate

(3) Equivalent Knopp's solution devoid of P_2O_5 *plus* equivalent P_2O_5 as colloidal organic phosphates from the compost of lucerne and dicalcium phosphate

(4) Equivalent Knopp's solution devoid of P_2O_5 *plus* equivalent P_2O_5 as colloidal organic phosphates from the compost of lucerne alone.

In this study no account was taken of the small variations in the ionic ratios of the different culture solutions evidently brought about by the presence of organic matter in the colloidal organic phosphates. Observations made qualitatively were recorded for a period of 24 days. It was found that the growth of seedlings in solutions (3) and (4) was superior to that in the control (1), whereas the growth in (2) was inferior. The colour of the latter solution was much deeper than that of (3) and (4).

For further study the solution (2) was diluted to half the strength with respect to P_2O_5 content by adding 1200 c.c. of the Knopp's solution devoid of P_2O_5. The colour of the resultant solution became lighter and almost of the same depth as in (3) and (4). The solution was placed in two vessels, 1200 c.c. in each, and the experiments were repeated with 12 seedlings of about the same size and weight in each along with the other culture solutions previously used. Observations were recorded for a period of five weeks.

The initial and the final weights of the seedlings were recorded as set forth in Table V. The differential growth of the seedlings could very well be visualized in the control and the rest of the nutrient solutions.

TABLE V.

The growth of ragi *seedlings in nutrient solutions having inorganic and organic phosphates in them separately*

No.	Nature of nutrient solutions	Weight in mg. of 12 seedlings		Difference	Per cent increase over control
		Initial	Final (After 5 weeks)		
1	Knopp's solution (Control)	4·4	10·2	5·8	..
2	Knopp's solution devoid of P_2O_5 + organic phosphates from the compost of lucerne + monocalcium phosphate	4·1	15·2	11·1	91·4
	Duplicate.— Do. Do.	4·3	15·5	11·2	93·1
3	Do. + organic phosphates from the compost of lucerne + dicalcium phosphate	4·2	14·8	10·6	82·8
4	Do. + organic phosphates from the compost of lucerne alone	4·3	14·5	10·2	76·0

It is evident that the duplicate experiments with solution (2) agreed well among themselves and the seedlings in them were somewhat better than those in solutions (3) and (4). In all the solutions (2), (3), and (4) the growth of *ragi* seedlings was practically of the same order and decidedly better than that in solution (1) which served as the control. The percentage increases of growth indicate clearly the superiority of colloidal organic phosphates over K_2HPO_4 present in Knopp's solution. With regard to the efficacy of organic phosphates derived from different sources it is found that the compost of lucerne and monocalcium phosphates is the best, next comes in order the compost of lucerne and dicalcium phosphate, and the last is the compost of lucerne alone. In actual field practice also it is observed that the composts of green manure and superphosphate or both ploughed in together always give better crop yields than either superphosphate or green manure applied alone.

The conclusion therefore emerges that colloidal organic phosphates can very well maintain the growth of seedlings and serve as better agents for supplying the phosphatic requirements of crops than inorganic phosphates present in Knopp's solution, or similar phosphates normally contained in the phosphatic fertilizers used in ordinary farm practice. Probably the presence of colloidal organic matter in these solutions helps the assimilation by plants of other food materials too —unlike the same in Knopp's solution—according to the hypothesis already described, by making colloidal contact of root-hairs with food materials.

Hutchinson [1923] has shown by field experiments that the application of previously fermented green-manure, sunn-hemp (*Crotalaria juncea*) with superphosphate gives greater crop returns in calcareous Pusa soils than the same ploughed in along with super. The green-manure combined with super, on the other hand, yields better crops than super alone. The advantage of using previously fermented green-manure obviously lies in the fact that the humus produced by fermentation can at once react with super which otherwise becomes reverted into insoluble phosphates on reacting with soil bases, rendering the formation of colloidal organic phosphates rather a slow process.

The recent work of Spencer and Stewart [1934] lends support to the contention as to the better efficiency of organic phosphates in soil. They showed that phosphates in organic form of the type formula $R(OH)_x(OPO_3M_y)_z$ escapes, to a marked degree, the fixation in soil which normally occurs to the phosphates applied in some inorganic forms. They experimented with organic phosphates of the above type prepared in the laboratory, such as, calcium mono-orthophosphate of glycerol $C_3H_5(OH)_2OPO_3Ca$ and potassium sorbityl di-orthophosphate $C_6H_8(OH)_4(OPO_3K_2)_2$. A highly calcareous soil did permit little phosphorus in the filtrate when a solution of pure monocalcium phosphate was allowed to percolate through it, whereas, under the same conditions, much phosphorus passed through the soil when the above organic phosphates were used for percolation. Thus the permeation of phosphate in the organic form into deeper soil layers in close environs of plant roots is assured. This is also supported by the theory put forward by Ramann [1911] and Comber [1922] which suggests a distinct possibility of the plant roots absorbing phosphate direct, probably through contact with the soil colloids and also by the hypothesis of Greenhill [1930], according to which, ' solid phase ' feeding of phosphoric acid by the roots of crops is probable.

Summary and general conclusions

1. Organic phosphorus complexes are formed in the soil by the combined action of decaying organic matter and phosphatic fertilizers. They were qualitatively isolated by dialysis from the compost of lucerne alone, and also from lucerne composted with monocalcium and dicalcium phosphates separately.

2. These phosphates are soluble in water, neutral in reaction, and possess colloidal properties. They remain in a highly dispersed state in the soil and have been shown to be more available to plants by water culture experiments than the inorganic phosphates of phosphatic fertilizers used in ordinary farm practice, which are generally insoluble or eventually become so on reacting with soil bases.

3. The beneficial action of these colloidal organic phosphates resulting from the combined application of phosphatic fertilizers with organic manures in soils is explained on the basis of certain hypotheses mentioned in the paper, according to which, colloidal substances can serve as plant foods and the direct dissolution of plant food is rendered possible by the cell sap of root hairs.

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AVAILABILITY OF SUPERPHOSPHATE WITH DEPTH OF ITS PLACEMENT IN CALCAREOUS SOILS

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The past researches and the earlier work of Harrison and Das [1921] in this laboratory show that the soluble phosphoric acid of superphosphate is retained in the surface layers of calcareous soils as insoluble calcium phosphates by chemical combination with the large amount of calcium carbonate normally present in them; in consequence, the action of super is very localized, resulting in an uncertain and disappointing crop response to superphosphate in calcareous soils. Another contributory factor to this effect is due to the presence of 50 to 60 per cent of gypsum in commercial super, whose depressing action on the cropping of calcareous soils has already been shown by the author [Das, 1933].

Hockensmith, *et al.* [1933] studied the movement of phosphate in a calcareous soil by mixing a phosphate fertilizer with the surface 2 in. of soil in 5-gallon jars, and found the amount of phosphate leached through the soil to be exceedingly small. They also determined the effect of depth of placement on the availability of superphosphate in a calcareous soil by applying it at various depths in 5-gallon jars and found that the depth of application made a marked difference in the yield of alfalfa.

Midgley [1931] found that applications of super 3 in. deep gave 57 and 86 per cent more yields of grass and weeds respectively than the surface application. Similarly blue grass gave 46, 166 and 149 per cent more yields by surface 3 in. and 6 in. deep applications of super than no treatment of super. In the case of corn, sorghum and Sudan grass 110 to 167 per cent greater increases over control were obtained by 3 in. and 6 in. deep applications of super. He also found that under field conditions 60 to 100 lb. of P_2O_5 per acre as super applied on the surface are retained within the surface inch even after an interval of six months.

As the surface application of the fertilizer is a common farm practice, it appears to be a serious obstacle in the way of an extensive penetration of the soluble phosphoric acid of superphosphate into calcareous soils. It was, therefore, considered worthwhile to discover some means which would render a more extensive permeation of the phosphate into the soil below the plough line and thus result in a greater proximity of the applied phosphate to the plant's zone of absorption.

Although calcareous soils round about Pusa belonging to the Indo-Gangetic alluvium and containing 30 to 40 per cent of chalk are particularly deficient in available phosphates, their response to superphosphate is often erratic owing to the operation of factors discussed above. The surface application of the fertilizer which is usually followed in ordinary farm practice, accounts for this peculiar behaviour to a certain extent. Should, therefore, superphosphate be applied at different depths of such a soil, a variation in response is expected, depending on whether the crop grown is a shallow-rooted or a deep-rooted one; this observation may also throw considerable light in elucidating the problem of manuring these calcareous soils, particularly with superphosphate.

With this object in view, the present investigation was undertaken.

A sample of calcareous Pusa soil containing about 33 per cent of calcium carbonate was collected from a fallow plot for pot experiments in 1933. Four pots of similar dimensions, e.g. 12 in. in diameter and about 22½ in. high formed a group and received similar treatment. The pots contained 50 kilos of air-dry soil in each. A basal dressing of potash and nitrogen was given to all the pots at the rate of 80 and 100 lb. per acre or 40 and 50 mg. per kilo of soil as sulphates of potassium and ammonium respectively. Phosphate (P_2O_5) was applied to different

groups of pots at 100 lb. per acre or 50 mg. per kilo of soil as superphosphate at different depths, e.g. at surface, and 4, 8, 12, and 16 in. below the surface. The pots were watered from the top to get different degrees of diffusion, if any, and 16 per cent of moisture was maintained in the soil throughout the experiment. Mustard was sown on 8 November 1933 and the crop harvested on 10 March 1934.

Although the weights of both grain and straw per pot were recorded separately, only the yield of grain is given in Table I.

TABLE I

The yield of mustard with the placement of superphosphate

Treatment	Replications				Mean yield in gm.	Percentage increase over surface application
	1	2	3	4		
Super at surface	29·6	28·8	31·2	23·6	28·30	..
„ 4 in. below surface	44·5	45·2	37·6	41·9	42·30	49·5
„ 8 in. below „	35·9	35·1	38·9	34·5	36·10	27·6
„ 12 in. below „	41·3	36·3	33·2	31·4	35·55	25·6
„ 16 in. below „	37·1	36·2	30·0	31·8	33·78	19·4

Standard error for comparison of mean yields by Fisher's [1932] analysis of variance = 2·386

Critical difference for $P=1$ per cent = *7·03*

Critical difference for $P=5$ per cent = *5·09*

From Table I it is evident that all the deeper treatments of super have produced 19 to 50 per cent higher yields of mustard than the surface application. Further, the differences in mean yields of grain between surface and every other treatment of super are highly significant, being greater than the critical value of difference for one per cent level of significance in every case except the 16 in. application, where holds 5 per cent level of significance. Super placed 4 in. deep produced the maximum crop and gave highly significant yield when compared with any of the treatment tried. Among the last three treatments there is no significant difference of mean yields. Mustard being a shallow-rooted crop, appears to derive for maximum crop production its requisite phosphatic nutrition from the soil where super has been placed 4 in. deep.

After the harvest of mustard crop was over, 4 in. soil borings of 20 in. deep soil from each of the differently treated groups of pots and also from a pot of untreated Pusa soil which served as the control for comparison were taken from the surface downward. As these pots were watered for about four months during the period of growing the mustard crop, the super applied to the pots could leach downward, if possible. These soil samples were examined for total phosphate in order to discover the progressively downward leaching of the phosphate, if any. The results obtained are given in Table II.

TABLE II

Total phosphate contents of 4 in. soil borings from pots where superphosphate was applied to different depths at the rate of 50 mg. of P_2O_5 per kilo of soil and also from the control pot of untreated Pusa soil

Treatment	Mg. total P_2O_6 per 100 gm. of soil				
	0-4 in.	4-8 in.	8-12 in.	12-16 in.	16-20 in.
Control	104	104	104	100	104
Super at surface	*110*	101	101	104	104
„ 4 in. below „	101	*107*	99	104	104
„ 8 in. „ „	104	104	*109*	101	104
„ 12 in. „ „	104	104	104	*115*	100
„ 16 in. „ „	104	99	104	99	*107*

The figures in italics in Table II show the her concentrations of P_2O_5 in the depths where per has been applied. At the other depths the ncentration of P_2O_5 is almost of the same mag- ude as in the corresponding depths of the ntrol where no super has been applied. In er words, it never exceeds the limit of P_2O_5 tent in any depth of the control pot. The clusion therefore emerges that phosphate s not leach downward beyond 4 in. from the th of its application, but remains within the n. area of the depth of its placement in the ..

The foregoing cropping results were secured with a *rabi* (winter) crop. Next it was considered worthwhile to obtain further confirmatory data with a *kharif* (summer) crop. For this purpose pot experiments were conducted on similar lines in 1934 with the same calcareous Pusa soil. Super was placed at 3, 6, 9 and 12 in. below the surface soil. *Ragi* (*Eleusine coracana*) was sown on 20 June and the crop harvested on 5 October, 1934. The yield of grain of individual pots is set forth in Table III.

From Table III it is evident that the differences in mean yields of grain between the surface appli-

TABLE III

The yield of ragi (Eleusine coracana) *with the placement of super*

Treatment	Replications 1	2	3	4	Mean yield in. gm.	Percentage increase or decrease over surface application
per at surface	48·7	47·6	44·9	46·1	46·83	..
,, 3 in. below ,,	40·4	34·9	33·9	31.4	35·15	—25·0
,, 6 in. ,, ,,	70·6	63·9	66·6	68·4	67·38	+44 0
,, 9 in. ,, ,,	59·7	63·2	60·1	61·1	61·28	+30·9
,, 12 in. ,, ,,	44·3	46·0	43·9	42·2	44·10	—5·8

tandard error for comparison of mean yields by ner's [1932] analysis of variance = 1·784
Critical difference for $P = 1$ per cent = *5·26*
Critical difference for $P = 5$ per cent = *3·80*

ion of super and super placed only 6 or 9 in. p are highly significant being greater than the ical value of difference even for one per cent el of significance. On the other hand, such erences in mean yields of grain between the face and 3 in. or 12 in. deep treatment of super negative, and consequently no profitable onse can be expected on the application of per at these depths for a *kharif* crop like *ragi*. per placed 6 in. deep produced the maximum p and gave highly significant yield when com- ed with any of the treatments tried. Next ne in order the yield from the 9 in. deep lication of super.

Thus, the cropping experiments with a *kharif* p like *ragi* and a *rabi* crop like mustard have wn that the application of superphosphate 4 in. 6 in. below the surface gives the maximum p production in calcareous soils. This may be ily effected by means of deep ploughing in inary farm practice.

SUMMARY AND GENERAL CONCLUSIONS

The present investigation was instituted to cover some means which would render a more ensive permeation of the phosphate into the l below the plough line and thus result in a greater proximity of the applied fertilizer to the plant's zone of absorption. In order to do this, superphosphate was applied at different depths of a calcareous Pusa soil in two series of pots, in one of which mustard, a *rabi* (winter) crop and in the other *ragi* (*Eleusine coracana*), a *kharif* (summer) crop were grown. The cropping results showed that the application of super from 4 in. to 6 in. deep gave the maximum crop production.

After the harvest of mustard crop was over, 4 in. soil borings from surface downward of the different groups of pots where superphosphate was applied at surface, and 4, 8, 12, and 16 in. deep were examined for total phosphate contents. The results showed that phosphorus did not leach downward beyond 4 in. from the depth of application, but remained within the 4 in. area of the depth of its placement in the soil. This is fully in agreement with the observation of other workers.

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CONDUCTOMETRIC METHOD OF ANALYSIS AS APPLIED TO SOIL SURVEY WORK

III. THE ESTIMATION OF THE SOLUBLE SULPHATE AND CHLORIDE CONTENTS OF SOILS*

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(With one text-figure)

The soils from areas subjected to arid climatic conditions contain soluble salts in varying degrees. The main salts present in the alluvial soils of the Punjab are sulphate and chloride of sodium. For characterizing such soils it is necessary to determine the total soluble salts and at times the exact proportion of the main salts present. The analyses are usually done with water extracts of soils which are prepared from soil suspensions of definite soil-water ratio (one part of soil and five parts of distilled water are usually employed) after shaking them for some time and extracting the suspensions with Houston pump. The chlorides are estimated volumetrically and, unless the soil extracts are coloured, that work does not present much difficulty. The usual method of estimating sulphates gravimetrically is, however, fairly tedius and time consuming. A quicker method for such analysis and capable of use in the field would be extremely helpful for workers engaged in soil survey work. The present paper describes a method based on the conductometric principles for such analysis.

Previous work

Britton [1934] describes a number of methods used for conductometric analysis. The majority of these are based on the use of alternating current in the equipment to avoid polarization effects. The oscillating thermionic valve is most commonly employed, the advantage being that the frequency of the A.C. can be varied at will to suit experimental requirements. Callan and Horrobin [1928] used the carborundum crystal detector in place of the thermionic valve in the circuit, thus simplifying the equipment for conductometric analysis considerably. Following their suggestion, Hoon [1932] contrived a simple equipment for the conductometric estimation of sulphate and chloride contents of soils. Although the method was fairly quick and simple it was primarily suited for use in the laboratories or places where electric current was handy to drive the commutating arrangement employed therein.

Some equipments for conductometric analysis involve the use of direct current. Puri and Anand [1937] suggested an equipment for determining the salt content of soil suspensions in which a high tension dry battery was employed for direct current. The Dionic Water Tester, another convenient outfit present in almost every soil laboratory for measuring the salt content of solutions, water samples, etc., also involves the use of direct current. Hoon, Malhoutra and Jain [1939] adopted Dionic Water Tester for determining the percentage salt content of soils.

The use of the Dionic Water Tester

As the Dionic Water Tester yields an almost constant potential of about $100 \pm 0 \cdot 25$ volts for a few seconds it was considered of interest to examine the possibility of employing this instrument for the conductometric titration work. Rae [1931] employed the Dionic Water Tester for titrating acids and alkalies by taking inconvenient volumes of the two solutions of decinormal strength. No reference, however, had come to our notice of the use of this apparatus for titration of solutions involving precipitation of any of the products of reaction. As this apparatus had been adopted for the determination of the percentage soluble salt contents of soils an attempt was made to see if it could also be used for the conductometric titration of the sulphates and chlorides in the water extract of soils.

Details of the present method

(*a*) *Equipment*

The main requirements are the conductivity meter, the arrangement of movable and fixed electrode complete with flexible lead but without the outer glass container and a wide mouthed bottle of, say, four ounces capacity to serve as a vessel for carrying the titration. Bottles Nos. 2410 and 2412 (A. Gallenkamp & Co., Ltd.; Catalogue for laboratory apparatus and equipment, 11th Edition) are very convenient for the latter purpose. Somewhat bigger length of the movable electrode, than the one originally fitted in the standard form, was employed. This simple alteration was found very helpful in as much as it made possible the titration of even solutions with

* For Parts I and II of this series please refer to serial numbers 3 and 4 of the references given at the end of the paper

y low conductivities. A standard length the electrode or of the glass separator tube was necessary for our persent work as we required y comparative and not absolute values of ductivities.

Titration technique

A known volume of the soil extract is taken in wide-mouthed bottle and neutralized with ndard HCl using methyl orange as indicator decompose carbonates, bicarbonates, etc. To bid the dilution effect, the initial quantity of the ract is so chosen as not to use more than 2 c.c. the precipitant. A preliminary qualitative t with barium chloride solution is found helpful deciding the point. The volume is made to c.c. with distilled water and its conductivity ed. Seminormal solution of barium nitrate is n added from a small sized burette, reading ferably to 0·05 c.c., in lots of 0·2 c.c. or less h time. After each addition of precipitant the tle is stirred vigorously to precipitate out ium sulphate as completely as possible and the ductivity of the solution is noted after shaking h time till a constant value is obtained. In course of the titration a stage is invariably ched when the conductivity suddenly shoots indicating that the whole of the sulphate in the ution has been completely precipitated and e barium nitrate is present in excess. When s point is reached two or three further small itions of the precipitant are made and the ductivity of the solution noted after each tion. The conductivity values noted during titration are plotted against the volume of the cipitant added each time. The curve thus ained manifests invariably a kink which cor- onds to the end point of the reaction.

The conductometric estimation of the chloride ntent of the soil extracts is done on lines similar those described for estimation of sulphates cept that the initial neutralization of the alkali- y of the extract is done with standard nitric- d or sulphuric acid and the standard solution silver nitrate is employed as the precipitant. the precipitation of silver chloride in this case immediate no vigorous shaking, as required the case of sulphate titration, is necessary.

GRAPHIC REPRESENTATION OF THE RESULTS

Using the present technique curves were obtain- for the titration of standard solutions of sodium phate and sodium chloride with barium nitrate d silver nitrate respectively. These were alogous to those obtained by other methods. e results of titration of sulphates in soil extracts are graphically represented in Fig. 1, and show that kinks representing the end points are clearly obtained.

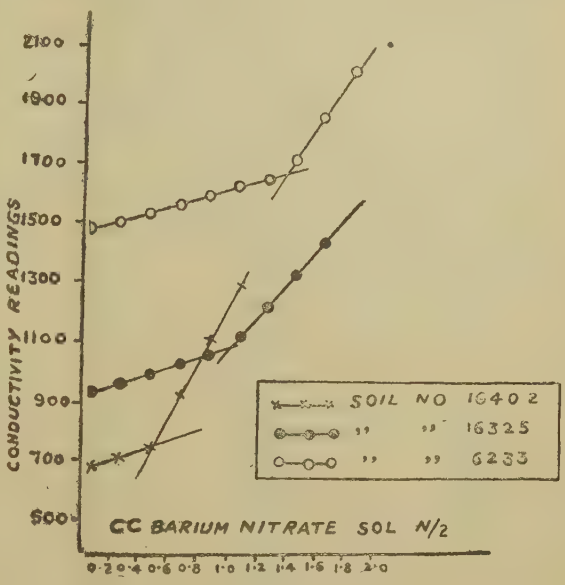

FIG. 1

A curious difference was noticed in the nature of the titration curves obtained with pure salt solutions and soil extracts. While in the case of the former there is no change in conductivity until the end point, in the case of the latter the conductivity changes constantly. The explanation that can be offered for this discrepancy at the present stage of this investigation is that it is due to some peculiar soil factor affecting the extract. A strong support is lent to this view by the observation that sodium sulphate when added to a soil extract containing initially little sodium sulphate gives a titration curve analogous to that of soil extract given in Fig. 1. The exact nature of the soil constituent causing this discrepancy is under investigation.

To compare the results of sulphates in the water extracts of soils the estimations were done for a number of soils both conductometrically and gravimetrically. The results are given in Table I and comparison between the percentage sulphate content as determined by the two methods is very good.

BARIUM ACETATE SOLUTION AS PRECIPITANT

Britton [1934] suggests the use of the barium acetate solution as the precipitant for the conductometric titration of sulphates. It was tried with the present technique also. The curves obtained were similar to those obtained by other

TABLE I

A comparison of the sodium sulphate in the water extracts of soil samples estimated gravimetrically and conductometrically

Sr. No.	Percentage gm. of Na_2SO_4 estimated gravimetrically	Percentage gm. Na_2SO_4 estimated conductivetically
1	0·06	0·07
2	0·06	0·07
3	0·09	0·10
4	0·09	0·10
5	0·14	0·14
6	0·18	0·19
7	0·14	0·13
8	0·15	0·12
9	0·11	0·13
10	0·13	0·11
11	0·19	0.19
12	0·13	0·14
13	0·17	0·18
14	0·14	0·12
15	0·16	0·18
16	0·19	0·18
17	0·19	0·18
18	0·20	0·19
19	0·11	0·11
20	0·15	0·15
21	0·25	0·23
22	0·28	0·27
23	0·24	0·25
24	0·22	0·20
25	0·26	0·25
26	0·27	0·26
27	0·27	0·28
28	0·29	0·32
29	0·21	0·18
30	0·23	0·23
31	0·28	0·28
32	0·21	0·22
33	0·29	0·32
34	0·21	0·22
35	0·22	0·24
36	0·29	0·28
37	0·39	0·37
38	0·36	0·34
39	0·33	0·32
40	0·37	0·35
41	0·31	0·31
42	0·34	0·36
43	0·30	0·29
44	0·30	0·32
45	0·37	0·40
46	0·38	0·37
47	0·37	0.36
48	0·40	0·39
49	0·49	0·50
50	0·43	0·38
51	0·43	0·46
52	0·43	0·46
53	0·53	0·51
54	0.54	0·56
55	0·50	0·52
56	0·58	0·55
57	0·58	0·60
58	0·61	0·61
59	0·66	0·65
60	0·64	0·60
61	0·62	0·61
62	0·65	0·64
63	0.80	0·82
64	0.89	0·82
65	0.98	0·88
66	0.97	0·89
67	1.03	0·95
68	1.33	1·49
69	1·23	1·28
70	1·44	1·37
71	1·39	1·34
72	1·05	1·01
73	1·35	1·31
74	2·90	2·84
75	2·84	2·76
76	2·91	3·01
77	2·44	2·33
78	3·12	3·05

methods. Here, due to the low mobility of CH_3COO' ion, the angle of intersection between the two parts of the curve is smaller and thus the indication of the end point is clearer than in the case of barium nitrate.

SUMMARY

A technique of conductometric titration of sulphates and chlorides in the water extracts of soils based on the use of the Dionic Water Tester equipment has been described. The method is extremely simple and the outstanding advantage is that it does not require the use of any electric mains, battery, etc. and, therefore, can be used both in the laboratory and the field.

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STUDIES ON THE FALSE-SMUT DISEASE OF PADDY CAUSED BY *USTILAGINOIDEA VIRENS* (CKE.) TAK.

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The false-smut disease of paddy caused by *Ustilaginoidea virens* (Cke.) Tak. occurs all over Burma but ordinarily does not cause any appreciable damage sufficient to warrant treatment. In the year 1935 the disease appeared in a serious epidemic form at Hmawbi and the surrounding tracts. Elsewhere the disease was sporadic and the loss negligible except at the Agricultural Station, Akyab.

At Hmawbi, where detailed investigations were carried out, it was found that the chief centre of infection lay in the Agricultural Farm where, in some of the plots, not a single plant free from the disease was found and the number of grains infected in these plots amounted to about six per cent. In the surrounding cultivators' areas the intensity of the disease was slightly less but farther away it was practically negligible.

In the year 1936 the disease again appeared but in a milder form and in 1937 the amount of infection was extremely light. From 1938 to 1941 the disease did not cause any anxiety.

Description of the disease

The fungus attacks the ovaries and transforms them into large roundish green masses which may be about twice the diameter of normal grains. The glumes remain unaffected. In each panicle only a few grains irregularly distributed, are usually attacked. On cutting a cross section of an affected grain, it is seen that the central portion consists of a white compact mass bounded by an orange-yellow zone and surrounded by a powdery dark green layer.

The young ovary is attacked by the fungus at an early stage of its development and in 10 to 15 days after the opening of the flower it is transformed into a hard sclerotial mass covered over with a green powder which consists of spores. The centre of this structure is composed of a pseudo-parenchymatous tissue but towards the periphery the hyphae have a radial arrangement. The spores are formed laterally on these radial hyphae. The youngest spores are almost colourless and are found on the hyphae near the base. Farther out the spores are orange-yellow in colour and near the surface, where they are quite mature, they are dark olive green. The fully formed spores are spherical with a granular coating. They measure from 4 to 6 μ in diameter.

Cultural studies

Germination of the spores

Fresh sclerotial bodies were obtained from the farms at Hmawbi and Mandalay for the study of the germination of spores. The spores were transferred by means of a sterile needle into a tube containing melted plain agar medium at 45°C. The tube was then well shaken and the contents poured into a petri-dish and stored at laboratory temperature.

At the end of 24 hr. when the dishes were examined it was found that about 10 per cent of the spores had germinated each producing a short unbranched germ-tube. After another 48 hr., the germ tubes were found, profusely branched and septate and bearing clusters of small pear-shaped hyaline conidia at the tips. These secondary conidia were formed both terminally and laterally at the hyphal tips. The germination of the spores was limited to this extent in plain agar medium, but when the branched germ-tube along with the secondary conidia was transferred to a tube containing Quaker-oats medium it renewed its growth and in a faw days' time produced a white fluffy felt-like mycelium. The mycelium continued its growth and after about three weeks produced many white, compact, almost round, sclerotial bodies. The sclerotia later on turned orange-yellow and finally olive-green in colour and became slightly powdery in appearance. On examination they were found to correspond closely to those obtained from the host plant, in having a central white portion of compact hyphae bounded by an orange-yellow zone and finally surrounded by powdery olive-green layer consisting of mature spores. The spores obtained from these bodies germinated in the usual way and produced sclerotia.

When a suspension of secondary conidia in plain agar was plated, they were found to germinate in very much the same way as the parent spore. They became slightly swollen at first, then produced branched and septate germ-tubes bearing clusters of small pear-shaped hyaline conidia at the tips. These tertiary conidia were slightly smaller and their germ hyphae narrower and sparsely septate when compared with those obtained from the parent spores. When the germ hyphae along with the tertiary conidia were

transferred to tubes containing Quaker-oats medium the usual sclerotial bodies were obtained.

Sclerotia were obtained repeatedly in the laboratory in cultures made during the months November to February. There was no sclerotial formation in cultures made during March to August and the growth of mycelium was also not typical, being mainly flat and devoid of any aerial hyphae.

Literature dealing with the study of this fungus *Ustilaginoidea virens* (Cke.) Tak. is very scanty and it appears that so far only one previous investigator, Brefeld [1895], had succeeded in obtaining sclerotia and ripe spores in cultures. Fulton [1908] and Butler [1913], in spite of their repeated attempts, failed to get sclerotial masses in culture. This failure may possibly have been due to their incubating the cultures at comparatively high temperatures.

Growth in relation to temperature

Petri-dishes containing Quaker-oats medium were inoculated with small pieces of hyphae according to the technique followed by Seth [1934] and incubated at different temperatures. Four dishes were used for each temperature. The radial spread of the fungus was measured periodically. The final measurements taken after 29 days of growth are given in Table I.

It will seen from Table I that the fungus fails to show any growth at 34°C. The optimum temperature appears to be in the vicinity of 26°C. When the plates incubated at 34°C. and 37°C. were transferred to lower temperatures, no growth took place, indicating that the fungus had been killed by prolonged exposure to these temperatures.

Longevity of the spores

Sclerotial bodies of the fungus from *Ngasein* type of paddy were collected at Hmawbi during the first week of December 1936 and stored at Mandalay in glass tubes at laboratory temperature. The spores from these were periodically examined, by growing them on plain agar medium to find out how long they could remain viable. The results obtained are given in Table II.

It will be noted that the spores can remain viable up to a period of only about 8 months from the time of their formation.

Germination of sclerotia

(*i*) In order to study the germination of the sclerotial bodies, four glass troughs filled with soil obtained from a paddy field at Mandalay and four filled with sand were taken and the sclerotial bodies sown in these at a depth of about one inch. Two troughs containing paddy-field soil and two containing sand were flooded with water once a week to keep the soil and sand thoroughly wet. The remaining troughs were watered whenever the contents in them had dried. Sclerotial bodies were sown on 3 January 1936. Six months later each sclerotial body was found to have been reduced to a dark powdery mass consisting of spores only and there was no indication of the production of any ascus-bearing structure. These spores failed to germinate in nutrient media in spite of repeated attempts.

(*ii*) In another method, small pieces of the central white compact tissues of the sclerotial bodies were transferred to Quaker-oats medium. The procedure adopted was as follows :

Sclerotial bodies were dipped in a 0·01 per cent mercuric chloride solution containing a small quantity of ethyl alcohol for one minute and then repeatedly washed with sterile distilled water. These were then placed in a glass dish containing sterile water and cut in the form of small discs by means of a sterilized scalpel. Central tissues

TABLE I

Growth in relation to temperature

Temperature °C.	Radius of the colony in mm.	Remarks
37	..	No growth
34	..	No growth
32	16·5	Mycelium flat, not typical
30	19·75	Mycelium flat, not typical
29	23·0	Mycelium mainly flat, very slight aerial growth, not typical
28	23·0	Mycelium mainly flat, very slight aerial growth, not typical
26	25·0	Mycelium white fluffy, typical. Sclerotia and spores formed
22	21·75	Typical growth, tendency towards formation of sclerotia. Sclerotia and spores formed seven days later

TABLE II

Longevity of the spores

Date on which cultures made	Remarks
22 Dec. 1 936 .	Spores germinated
6 Jany. 1937 .	Spores germinated
11 March 1937 .	Spores germinated
30 June 1937 .	Spores germinated
4 Aug. 1937 .	Spores germinated
30 Aug. 1937 .	Spores failed to germinate
6 Sept. 1937 .	Spores failed to germinate

from these discs were then cut out and transferred to tubes containing Quaker-oats medium and incubated at the laboratory temperature.

Growth commenced on the 3rd day and in another three weeks' time, many typical sclerotial bodies developed. No ascus-bearing structures appeared though the cultures were kept in the laboratory for a period of over three months

Inoculation experiment

In order to find out if the disease could be reproduced under field conditions, the inoculation of flowers just at the time of opening and of the grains in the milk stage was carried out at the Mandalay Farm. The method consisted of inserting the spores within the glumes by means of a sterilized needle or spraying with a suspension of spores in sterilized water. The spores of the preceding year, fresh spores as soon as they could be obtained and spores obtained in cultures were used. Some of the flowers after treatment were enclosed in tubes and some left exposed. The total number of flowers and grains thus treated was 2109. The inoculations were carried out during the third week of November, 1936. At the time of the examination in January, 1937, it was found that the majority of the inoculated seed had matured quite normally and all were free from infection.

Another experiment was carried out in pots. Seed of *Ngasein* paddy (C 24-71 type) which is known to be very susceptible to the disease, was obtained from Hmawbi. The seed was sown on 4 September 1937, after receiving the following treatments :

(*a*) Seed dusted with fresh spores obtained from Hmawbi Farm.

(*b*) Seed dusted with spores obtained in cultures.

(*c*) Untreated seed.

On 4 January 1938, when the final examination was carried out, it was found that all plants had matured normally and all remained free from infection.

SUMMARY

1. The fungus attacks individual paddy grains and transforms them into large green round masses which may be about twice the diameter of normal grains.

2. The spores on germination in cultures give rise to sclerotial bodies closely resembling those found under natural conditions.

3. The optimum temperature for the growth of the fungus is in the vicinity of 26°C. Prolonged exposures at temperatures above 34°C. kill the fungus.

4. The spores can remain viable up to a period of only about eight months.

5. Sclerotial bodies failed to produce any ascus-bearing structures.

6. Inoculation of flowers and of the grains in the milk stage failed to produce infection. Seed dusted with spores produced normal and disease-free plants.

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SUGARCANE VARIETAL TRIALS IN THE DECCAN CANAL TRACT

II. PERFORMANCE OF VARIETIES IN DIFFERENT PLANTINGS AND RATOONING

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In the canal tract of the Bombay Deccan, it is customary to plant cane at different times of the year. Generally there are three well defined periods of planting, viz. (1) *Adsali* or post seasonal planting starting in June, (2) Pre-seasonal starting in October, and (3) *Suru* starting in January. The main re son for the introduction of the first two types of plantings is to secure higher cane tonnages by lengthening the period of growth. Further as they come to maturity and harvest earlier than the January planting, cultivators are able to secure higher prices for their *gul* and the factories to extend the duration of the milling season by starting the working of the factory early. It was, therefore, considered essential to conduct trials of some of the improved varieties selected previously [Vagholkar and Patwardhan, 1940] at these plantings in order to find out their suitability. Simultaneously, the ratooning power of these varieties as well as the best planting suitable for ratooning was also tested by ratooning these plantings.

Material and method

Five promising varieties—Co 360, 407, 408, 413 and 419 were grown in these plantings of July, October and January in a split plot design of layout with plantings as main plots and varieties as sub-plots. The replications were three and the experiment was conducted for a period of three seasons, plantings being done during the first week of the month in each case.

The basal manuring was common to all the plantings and consisted of 30,000 lb. of compost prepared mainly from sugarcane trash and 100 lb. of P_2O_5 in the form of superphosphate. As regards nitrogenous topdressings, July planting received 300 lb. N in the proportion of one of sulphate of ammonia to two of ground-nut cake while other plantings received 225 lb. N in equal proportions of these ingredients. Harvesting was done when the maximum brix and purity were attained in each planting, which took about 17 to 17½ months for July planting, 14 to 14½ months for October planting and 13 to 13½ months for January planting from the date of planting. All these plantings were ratooned after the harvest and the ratoon crop received a common dose of topdressing of 225 lb. N in equal proportion of sulphate of ammonia and ground-nut cake.

Presentation of data

Combined plantings

(1) *Germination.* The final germination counts which are taken at the end of six weeks in the July and October plantings and at eight weeks in January planting are given in Table I. The seed rate in all these plantings was 10,000 three-budded setts per acre. The figures are given as average of three seasons as the trend from year to year has been practically similar.

Table I

Final germination counts

(Area one cent)

(Average of 3 seasons)

Time for planting	Varieties					Mean for planting**
	Co 360	Co 407	Co 408	Co 413	Co 419	
July	173*	214	203	243	218	210
October	160	197	146	213	202	184
January	179	261	221	241	238	228
Mean for varieties †	171	224	190	232	219	

*C.D. for any two treatments 10·2 **C.D. for means for planting 7·89 † C.D. for means for varieties 5·93

Plantings are quite significant, the order being January, July and October, the last showing the least germination in the case of all the varieties. This is surprising as both from the standpoint of temperatures and the nature of the planting material both the latter plantings have been in a favourable position. The planting material is obtained from a crop 12 months old in the case of each planting and as such it would consist of more immature canes in the case of July and October plantings. So also the minimum temperatures throughout the period of germination in both these plantings remain higher than 50°F. and as such are in fact favourable to rapid germination [Rege and Wagle, 1939]. The fall in total germination in both these plantings seems to be, therefore, due to the soil conditions as affected by rains. In the case of July plantings rains which are received often during the period of germination would keep the soil continuously moist and this is known to adversely affect the germination. In October planting it is difficult to secure good tilth owing to the obstruction to proper cultivation operations as a result of heavy rains in September. Both these adverse factors are not experienced in the January planting. These comparative studies in plantings have thus enabled one to get a proper estimate of the influence of soil on germination.

As regards the varieties, Co 413 has given the best germination and Co 360 the worst, the other varieties being intermediate, Co 408 seems to be more susceptible to the soil conditions than others.

(2) *Tillering and borer counts.* During the tillering phase periodical records have been kept of the plant population and the borer affected plants; but for the limitations of space only the figures at the time of earthing, which represent the maximum number of living plants, are given in Table II with the figures of total percentage of borer damage during this period. In addition the figures are given of the canes at harvest and their

rcentage success on the maximum population. l the data are the average of three seasons as hough some seasonal fluctuations are evident e trend from season to season has been practi-lly similar both in the case of the varieties and ntings.

The shoots at earthing represent the maximum ering capacity in the varieties which is the ghest in Co 413 and the lowest in Co 360 of all e varieties under experimentation. Among the ntings, these shoots are low in July planting compared to other plantings which is mainly e to the heavy damage of borer in this planting, which all the figures are exclusive. In spite this smaller number of shoots at earthing, the ly planting has given the highest number of nes at harvest (Table III) which is contrary to pectations as after the operation of earthing e damage of stem borer is found to be rare in all the plantings. There is still, however, a mortality of shoots after earthing which is greater in the October and January plantings as is evident from the figures of percentage success both at two months after earthing and at harvest. The former figures of percentage success show that this mortality is mainly due to the smothering of small shoots by the operation of earthing and it is evident that such small shoots are more in the October and January plantings than in the July one. As regards the borer damage there is nothing much to choose between the varieties. Only Co 419 and Co 407 have given some indications of lower susceptibility than others. It would, however, be possible to reduce its depredations to a very great extent by adjusting the plantings.

(3) *Harvest data.* These are given in Table III as average of three seasons. There is a significant fall in cane tonnages from July to January plantings.

TABLE II

Developmental data

(*The figures of counts are reduced to one cent area*)

(Average of three seasons)

	Co 360	Co 407	Co 408	Co 413	Co 419	Mean for planting
July planting						
Shoots before earthing	517	749	797	1141	656	772
Per cent success—after 2 months—on (1)	90·1	85·4	80·2	79·4	83·7	83·8
Per cent success at harvest on (1)	76·6	66·5	60·3	43·5	68·3	63·0
Per cent borer attack	20·2	10·1	20·5	16·1	12·8	15·9
October planting						
Shoots before earthing	569	934	873	1385	875	927
Per cent success—after 2 months—on (1)	72·4	47·5	49·7	34·1	53·4	51·4
Per cent success at harvest on (1)	68·50	44·83	46·34	31·67	50·62	48·3
Per cent borer attack	2·1	1·4	1·3	1·3	1·0	1·4
January planting						
Shoots before earthing	465	970	847	1184	849	863
Per cent success—after 2 months—on (1)	73·1	42·5	49·0	43·1	53·5	52·2
Per cent success at harvest on (1)	61·31	36·91	43·23	32·99	47·33	44·35
Per cent borer attack	7·0	5·2	5·9	4·4	6·5	5·8
Mean for varieties						
Shoots before earthing	517	884	839	1237	793	854
Per cent success—after 2 months—on (1)	78·5	58·5	53·0	52·2	63·5	62·5
Per cent success at harvest on (1)	68·8	49·41	49·96	36·05	55·42	51·88
Per cent borer attack	9·8	5·6	9·2	7·3	6·8	7·7

far as the October and January plantings concerned, the higher tonnages in the former entirely due to the longer period it gets for elopment as nitrogenous topdressings were same in both these plantings. Flowering is nitely seasonal invariably occurring some e during the months of October and November ording to the inherent characteristics of the ieties. It has been thus observed that all these three plantings practically flower at the same time according to the characteristics of the varieties and as a result the earlier plantings of July and October get a longer period for development than the January one. In the case of July planting, the increase in yields over the other plantings cannot, however, be entirely attributed to the longer period of growth as there has been an increase in nitrogenous topdressings by 75 lb. N,

the dose being 300 lb. N as against 225 lb. in other plantings.

Although the number of canes at harvest has shown similar gradient as in cane tonnages in these plantings, the increase in cane tonnages in July planting cannot be entirely ascribed to the higher number of canes, as weight per cane is also definitely higher. In the case of the other two plantings the higher tonnages in the October planting is mainly due to larger number of canes. In fact the first three varieties in this planting are showing a slight reduction in weight per cane than that in January planting. This low figure for weight per cane in this planting in spite of longer period available for growth clearly indicates that the system of manuring in both these plant ings with equal quantities of nitrogen is not correct one and it would be necessary to give higher quantity of nitrogen in the October plan ing than in the January one. Higher doses c nitrogen however leads to lodging of the cro specially in early plantings. In the case of Jul planting, for instance, lodging is observed fro May onwards when the wind velocity increase and in one such experiment with 1000 lb. N mor than 50 per cent of the crop was damaged due t driage, rat attack, etc., after lodging in the case c Co 419 eventually encouraging production of wate shoots. In general it is estimated that in th canal tract as a whole, the loss in the tonnages i

TABLE III

Harvest data

(Average of three seasons)

	Co 360	Co 407	Co 408	Co 413	Co 419	Mean for planting
July planting						
(1) Weight of canes in tons per acre	49·9	49·8	60·3	58·6	66·4	57·0
(2) No. of canes per acre	39,600	49,800	48,100	49,900	44,800	46,400
(3) Weight per cane in lb.	3·00	2·55	3·18	3·32	4·05	3·22
(4) Brix at 17·5°C.	19·12	19·51	19·70	19·27	20·59	19·64
(5) Sucrose per cent in juice	16·58	17·08	17·38	17·69	17·60	17·27
(6) Fibre per cent	12·41	14·88	13·36	12·70	13·01	13·27
(7) C. C. S. per cent	11·5	11·5	12·3	11·5	12·0	11·8
(8) C. C. S. in tons per acre.	5·65	5·69	7·21	6·72	7·97	6·65
(9) Net profit Rupees per acre	605	615	862	781	984	770
October planting						
(1) Weight of canes in tons per acre	42·0	40·6	49·3	51·4	54·9	47·6
(2) No. of canes per acre	39,000	41,900	40,500	43,900	44,300	41,900
(3) Weight per cane in lb.	2·52	2·31	2·11	2·75	3·00	2·54
(4) Brix at 17·5°C.	20·38	22·69	21·10	20·50	21·20	21·17
(5) Sucrose per cent in juice	18·03	20·39	18·84	18·99	18·87	19·02
(6) Fibre per cent	13·65	16·43	15·36	13·34	12·64	14·28
(7) C. C. S. per cent	12·5	13·7	12·8	13·6	13·3	13·2
(8) C. C. S. in tons per acre	5·25	5·54	6·27	6·96	7·29	6·26
(9) Net profit Rupees per acre	592	640	756	869	921	756
January planting						
(1) Weight of canes in tons per acre	36·0	39·1	42·8	46·7	48·5	42·6
(2) No. of canes per acre	28,500	35,800	36,600	39,100	40,200	36,000
(3) Weight per cane in lb.	2·82	2·36	2·55	2·59	2·82	2·63
(4) Brix at 17·5°C.	20·83	22·77	21·77	21·02	20·65	21·60
(5) Sucrose per cent in Juice	18·17	20·10	18·80	18·41	18·96	18·89
(6) Fibre per cent	11·98	15·95	16·92	14·55	12·76	14·43
(7) C. C. S. per cent	12·7	13·4	12·5	12·7	13·2	12·9
(8) C. C. S. in tons per acre	4·70	5·24	5·33	5·86	6·39	5·50
(9) Net profit in Rupees per acre	528	617	639	715	802	658
Mean for varieties						
(1) Weight of canes in tons per acre	42·6	43·2	50·8	52·2	56·6	49·1
(2) No. of canes per acre	35,700	42,500	41,700	44·300	43,100	41,400
(3) Weight per cane in lb.	2·78	2·41	2·61	2·89	3·29	2·8
(4) Brix at 17·5°C.	20·1	21·7	20·6	20·1	21·1	20·7
(5) Sucrose per cent in juice	17·59	19·19	18·34	18·36	18·48	18·39
(6) Fibre per cent	12·68	15·75	15·21	13·53	12·80	13·99
(7) C. C. S. per cent	12·2	12·9	12·5	12·6	12·8	12·60
(8) C. C. S. in tons per acre	5·2	5·49	6·27	6·51	7·22	6·14
(9) Net profit in Rupees per acre	580	624	749	788	902	728

TABLE IV

Periodical brix and purity readings in the combined plantings

(Average of three years)

Planting	Mid-October		Mid-November		Mid-December		Mid-January	
	Brix at 17·5°C.	Purity per cent	Brix at 17·5°C.	Purity per cent	Brix at 17·5°C.	Purity per cent	Brix at 17·5°C.	Purity per cent
Co 360								
July	18·5	87·6	18·3	87·1	18·3	86·8	..	..
October	19·2	88·0	19·5	88·9	20·5	90·1	..	..
January	..	..	16·9	81·8	18·7	86·2	19·9	88·8
Co 407								
July	20·2	90·2	19·3	88·3	19·8	89·4	..	..
October	19·1	86·9	20·8	89·3	21·5	88·6	..	..
January	..	..	17·7	80·5	20·6	85·6	22·1	87·7
Co 408								
July	17·7	86·2	18·8	39·4	19·1	89·8	..	..
October	17·3	85·4	18·8	88·5	20·4	89·2	..	..
January	..	..	17·1	84·1	19·3	88·0	20·7	89·4
Co 413								
July	18·3	88·5	18·6	88·9	19·4	90·1	..	..
October	16·9	85·8	18·7	88·9	20·4	90·2	..	..
January	..	..	16·9	83·3	18·9	27·6	20·2	89·1
Co 419								
July	19·0	89·9	19·6	89·4	20·0	87·7	..	..
October	16·4	81·4	17·7	84·0	20·5	89·2	..	..
January	..	..	15·9	78·1	19·0	84·8	20·6	86·3

TABLE V

Ratoon-developmental data

(The figures of counts are reduced to one cent area)

(Average of three seasons)

1	Co 360 2	Co 407 3	Co 408 4	Co 413 5	Co 419 6	Mean for planting 7
July planting						
Shoots at start	367	725	559	1176	667	699
Shoots before earthing	488	741	672	1085	693	736
Per cent success on before earthing count	63·7	51·2	56·7	43·0	54·0	53·7
Per cent borer attack	9·5	6·8	6·9	5·4	6·7	7·1
October planting						
Shoots at start	327	556	411	991	508	559
Shoots before earthing	429	531	581	759	551	570
Per cent success on before earthing count	70·1	66·0	62·1	56·3	64·9	63·9
Per cent borer attack	9·5	6·8	6·6	4·5	6·3	6·7
January planting						
Shoots at start	311	547	469	945	655	585
Shoots before earthing	393	559	566	961	644	625
Per cent success on before earthing count	69·4	57·7	64·9	40·7	54·9	57·5
Per cent borer attack	10·2	7·4	6·8	5·1	6·1	7·1
Mean for varieties						
Shoots at start	335	609	480	1037	610	614
Shoots before earthing	437	610	606	935	629	644
Per cent success on before earthing count	67·7	58·3	61·2	46·7	57·9	58·4
Per cent borer attack	9·7	7·0	6·8	5·0	6·4	7·0

TABLE VI

Ratoon-harvest data

(Average of three seasons)

1	Co 360 2	Co 407 3	Co 408 4	Co 413 5	Co 419 6	Mean fo planting 7
July planting						
(1) Weight of canes in tons per acre	29·35	29·04	30·24	38·07	37·63	32·87
(2) No. of canes per acre	31,100	37,100	38,100	36,700	37,400	38,200
(3) C. C. S. in tons per acre	4·26	4·16	3·98	5·29	5·43	4·62
(4) Brix at 17·5°C.	22·77	23·17	21·75	22·03	23·02	22·55
(5) Sucrose per cent in juice	20·63	20·97	19·46	20·01	20·54	20·32
(6) Fibre per cent in cane	13·41	16·35	15·31	14·82	13·68	14·71
(7) Sucrose per cent in cane	16·55	16·04	15·04	16·17	17·36	16·23
(8) C. C. sugar per cent	14·53	14·23	13·24	13·83	14·27	14·02
October planting						
(1) Weight of canes in tons per acre	30·17	29·14	27·60	39·80	34·64	32·27
(2) No. of canes per acre	30,100	35,000	36,100	42,700	35,800	35,900
(3) C. C. S. in tons per acre	4·34	3·75	3·48	5·42	5·07	4·41
(4) Brix at 17·5°C.	22·98	21·97	20·88	21·72	23·01	22·11
(5) Sucrose per cent in juice	20·57	19·35	18·56	19·65	20·75	19·77
(6) Fibre per cent in cane	13·52	17·07	15·55	14·88	13·61	15·32
(7) Sucrose per cent in cane	16·92	15·99	15·31	16·19	17·23	16·33
(8) C. C. sugar per cent	14·35	12·72	12·53	13·56	14·59	13·55
January planting						
(1) Weight of canes in tons per acre	30·04	27·61	26·65	39·21	34·08	31·51
(2) No. of canes per acre	27,300	22,300	36,700	39,100	35,300	32,100
(3) C. C. S. in tons per acre	4·39	3·85	3·50	5·21	4·94	4·38
(4) Brix at 17·5°C.	22·78	23·14	21·64	21·41	22·87	22·37
(5) Sucrose per cent in juice	20·75	20·83	19·41	19·46	20·57	20·20
(6) Fibre per cent in cane	13·75	17·19	15·88	15·59	14·27	15·33
(7) Sucrose per cent in cane	16·80	16·93	16·11	16·08	17·13	16·71
(8) C. C. sugar per cent	14·60	13·86	13·11	13·32	14·38	13·85
Mean for varieties						
(1) Weight of canes in tons per acre	29·85	28·60	28·11	39·08	34·5	32·22
(2) No. of canes per acre	29,500	31,500	37,000	39,500	36,200	35,400
(3) C. C. S. in tons per acre	4·33	3·92	23·65	5·31	5·15	4·47
(4) Brix at 17·5°C.	22·84	22·76	11·42	21·72	22·97	22·34
(5) Sucrose per cent in juice	20·65	20·05	19·14	19·71	20·62	20·10
(6) Fibre per cent in cane	13·56	16·87	5·58	15·03	13·85	15·12
(7) Sucrose per cent in cane	16·76	16·32	15·49	16·15	17·24	16·42
(8) C. C. sugar per cent	14·49	13·60	12·76	13·57	14·41	13·81

the July planted crop of Co 419 would be between 20 to 25 per cent while in the case of POJ 2878 it is much less. In the case of the experiment under discussion in which the nitrogenous topdressing was much lower than what is the common dose in this tract, the crop shows lodging

	Cane tonnages	Canes at harvest
C.D. for individual treatments	4·27	3040
C.D. for mean for planting	3·23	4157
C.D. for mean for varieties	2·71	1736

with the heavy rains of September only and even then this lodging is not very severe except in the case of Co 360. The actual damage to tonnage by lodging is found to vary between 5 to 10 per cent.

The lodging has further the deleterious effect on the quality of juice. In all these plantings harvesting is done when the cane shows very little further increase in brix and purity. The brix as well as the sucrose content is however much less in July planting than in others. The percentage C.C.S. which is a calculated figure according to Srivastava's formula shows a fall of more than 1 per cent in this planting, but owing to high cane tonnages the C.C.S. per acre comes to be higher than in the other plantings. This increase in

.C.S. is however insignificant as compared to hat in October planting although in cane tonnage he July planting is quite significant. It is in-eresting to note that for an increase of 9·4 tons f cane per acre in July planting, the increase in .C.S. per acre comes out to be only 0·39 tons. n the case of October and January plantings the ane shows similar figures of brix and purity at he time of the attainment of maximum maturity vhich comes up at a later stage in the January lanting. It is only in the cane tonnages that the ormer planting surpasses the other and gives herefore higher sugar per acre than the latter. Among the varieties Co 360 which possesses greater tendency to lodging, has shown lower ucrose content than others even in other plantings owing to lodging of some canes. The percentage ibre is low in the July planting as compared to thers.

Exactly similar trend is also observed in the net rofit per acre (Table III). These figures of net rofit are calculated on the pre-war figures of ex-enditure and the price of sugar. It would be een that on the whole there is very little difference etween July and October planting in this respect. Only the January planting shows a distinctly ower figure than the other two plantings. Periodi-al brix and purity figures at early stages from October onwards have shown that all the varieties lo not show early attainment of maturity in uly planting over October planting. On the ther hand, Co 360, because of its heavy lodging a July planting, has actually shown inferior erformance. Co 419 is the only variety which as shown distinctly early maturity in July. lanting throughout the period. The data for verage of the three seasons are given in Table IV.

atoon of plantings

The ratoons were kept after the harvest of these lantings by the middle of December in July lanting closely followed by that of October lanting. In the case of January planting, the arvesting was done in the last week of January. here was thus a delay in ratooning by about a onth in the case of last planting. A dose of 25 lb. N in equal proportion of sulphate of mmonia and cake was given in three topdressings y the usual method. The developmental data re given in Table V and the harvest data in able VI as average of the three seasons. It ould be seen that on the whole there is not much fference in the ratooning performance in these lantings and ratoons of the plant crop harvested y the end of January has come out as successful that of other plantings harvested in December. has been, however, observed from other experi-ental work that ratoons of later harvest are adversely affected specially due to the borer attack. The number of shoots both at start as well as at earthing up is much higher in the case of July planting than in others ; but this difference is not so much reflected in the canes at harvest. In addition the average weight per cane is slightly less in this planting resulting in the production of almost the same cane tonnages in the case of all the three plantings. As regards the quality of cane, there is some indication of the better performance in the ratoon of July planting. The percentage fibre is low, which has shown a higher percentage of C.C.S. in this planting than in others. The differences are not of sufficient magnitude to be significant. Among the varieties, Co 360 seems to be the worst ratooner and Co 413 the best from the standpoint of the production of shoots. There is also an indication of greater borer attack in Co 360 than in others. From the standpoint of tonnage, however, Co 360 equals Co 407 and Co 408 owing to greater weight per cane. Co 413 and Co 419 have given significantly higher tonnages than these varieties and among these even Co 413 seems to be superior to Co 419.

Sumamry and conclusions

In the Canal Tract of the Bombay Deccan, three distinct plantings are generally adopted in the case of sugarcane and investigations described in these pages deal with their relative importance as well as the suitability of the varieties for the plantings. Ratooning power of these plantings has also been studied. The conclusions are summarized below :

(1) There is a possibility of obtaining very low germination in the October planting due to the difficulty of conducting proper cultivation operations as a result of heavy rains in September which is a common feature in this tract. From the standpoint of germination January planting has come out the best. Among the varieties, Co 413 has shown a very good germinative power and Co 360 the least.

(2) July planting is characterized by a severe borer attack which reduces the number of shoots at earthing. In the case of other plantings although the number of shoots at earthing up remain much higher, a large mortality is caused during the operation of earthing by smothering of tillers, which seem to be more in these plantings than in the July one. As a result at harvest July planting has given a greater number of canes than others. Among the varieties, profuse tillering is observed in Co 413 which, however, is found to be not of much use from the standpoint of increasing the number of canes at harvest time.

(3) There is a significant increase in cane tonnages from January to July planting. In the

case of July planting it is due to both higher number of canes and weight per cane while in the case of October planting it is entirely due to increase in the number of canes. Owing to the poorer quality of juice, however, the C.C.S. per acre, is practically similar in both these plantings. There is also practically no difference in the net profit per acre in both these plantings. The only advantage of the July planting has been the attainment of early maturity in certain varieties as Co 419 which helps the sugar factories to start the crushing season earlier, and the cultivators to secure higher price for their *gul*. The January planting has shown a poorer performance in all respects. Among the varieties, Co 408 and Co 419 are found to be more suitable for July planting than others.

(4) The ratoons of all these plantings have shown practically similar performance at harvest. Among the varieties Co 360 seems to be the worst ratooner and Co 413 the best.

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RESEARCH NOTE

A PRELIMINARY NOTE ON THE QUICK SEDIMENTATION OF LIME JUICE FOR THE MANUFACTURE OF LIME JUICE CORDIAL

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(Received for publication on 31 August 1944)

Lime juice cordial, an important citrus fruit beverage is prepared from the clarified lime juice, i.e. juice from which all pulp, seeds, etc., have been eliminated. The method usually practised in this country by the manufacturers of lime juice cordial, for the clarification of lime juice consists of storing the juice (after addition of the preservative) in tall wooden vats and syphoning off the juice after sedimentation. This method takes two to four months (and even more) before the juice is clear enough for final filtration through filter presses for the preparation of the cordial. This necessitates a large number of vats and a huge storage space and consequently a good deal of capital of the manufacturers is locked up. In addition, the supply of the prepared cordial is often interrupted and delayed due to slow clarification process. A need has, therefore, been felt by the trade for sometime past, for a method which would quickly clarify the juice. The authors have studied this problem under the Special Fruit and Vegetable Preservation Scheme, Lyallpur, financed by the Imperial Council of Agricultural Research.

The following methods were tried for the clarification of the juice on a laboratory scale :

1. Passing the juice through Sharples' Super Centrifuge.

2. Filtration through (*a*) sand and charcoal filters, (*b*) Sietz filtering apparatus.

3. Treating the juice with (*a*) 5·0 per cent Fuller's Earth, (*b*) 6·0 per cent activated carbon, (*c*) Sand, (*d*) 5·0 per cent kaolin treated with tartaric acid, and (*e*) 0·1 to 5·0 per cent ordinary kaolin after ignition.

4. Juice treated as under (3) was filtered through Sietz apparatus and under suction in a Buchner Flask.

5. Treatment of juice with tannin and gelatin in different proportions (0·0085 per cent tannin in combination with 0·001126 to 0·03716 per cent gelatin).

Out of all the above treatments, the tannin-gelatin method gave the most encouraging results. Complete clarification of freshly extracted juice was obtained in this case in four to six days. Other treatments either did not yield a fair degree of clarity or were rather too slow in their action. No foreign undesirable taste was imparted to the juice clarified by the tannin-gelatin method.

The applicability of this method to old (stored) juice has yet to be tested. It is also proposed to give the method commercial trial in some factories this summer. Experiments are already under way, and the detailed results will be published as soon as commercial trials have been completed.

Note.—It is gratifying to note that the tannin-gelatin method developed by the authors, is now being successfully used in Mr Mitchell's squash and cordial factory at Renala Khurd (Punjab) for quick clarification of lime juice for cordial making. The remarks made by this firm about this method are reproduced below :

" We are greatly indebted to you for giving us this new method which has proved of immense use to us. As we have already pointed out our cordial manufacture would have been seriously delayed, if we had not got this method in time. Until now we have to keep large quantities of lime juice in stock and even when extracting new juice we keep about four months' supply of old lime juice as the new juice is supposed to take at least four months to clear up, but with this method, we hope to be able to reduce our stocks and make use of the supplies of fresh limes which can be had practically all the year round."

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